BUCKLING NEAR A HOLE
CENTERED IN A TENSION FIELD

JOHN F. DANIS

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1957
THESIS
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Letter on cover:

BUCKLING NEAR A HOLE CENTERED
IN A TENSION FIELD

John F. Danis

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BUCKLING NEAR A HOLE CENTERED IN A TENSION FIELD

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John F. Danis

AN INVESTIGATION OF THE BUCKLING CAUSED BY COMPRESSIVE FORCES EXISTING IN A THIN ELASTIC SHEET, WITH A HOLE IN THE CENTER, SUBJECT TO UNIFORM TENSION AT TWO EDGES

by

John F. Danis

Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

United States Naval Postgraduate School
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1957

Thesis
C155

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ABSTRACT

In a thin elastic sheet, with a hole in the center, subject to uniform tension on two opposite edges, a small area at the rim of the hole along the diameter of the hole parallel to the tension is in compression circumferentially.

This compression can cause buckling in this area. Such buckling may occur before the sheet yields at its point of maximum stress. Using Southwell's method of determining the critical buckling load, the relationship

$$\sigma_{cr} = KE \left(\frac{t}{d}\right)^2$$

is established, where σ_{cr} is the critical value of the uniaxial tension at a distance from the hole; d is the diameter of the hole; t is the thickness of the plate; E the (Young's) modulus of elasticity of the material; and K is an experimentally determined function of the ratio d/b of hole diameter to plate width.

This investigation was conducted at the United States Naval Postgraduate School, Monterey, California, in early 1957, by John F. Danis, Lieutenant, United States Navy, in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

The writer wishes to express his appreciation to Professors R. E. Newton and J. E. Brock, whose ideas, advice, and assistance made this paper possible.

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SYMBOLS

a -- Radius of Hole

a' -- Length of Sheet

b -- Width of Sheet

b' -- Constant Associated with Initial Curvature

d -- Diameter of Hole

h -- Thickness of Sheet (also designated t.)

k_y -- Expression for Curvature

l -- Length Measurement

t -- Thickness of Sheet

$w(x, y;P)$ - Primary Deflection due to Load

$w(x, y;0)$ - Initial Primary Deflection with no Load

x -- The Axis parallel to Applied Tension

y -- The Axis perpendicular to Applied Tension

A_i -- Coefficients which characterize Initial Deflection

B -- Strain gage reading for gages used to measure strain caused by change of radius of curvature at points of buckling.

B_o -- Initial Strain Gage Reading of B

B -- Difference in above. $(B - B_o)$

D -- Rigidity Function = $\frac{Eh^3}{12\,(1 - \nu^2)}$

D_1 -- Function of Initial Curvature = $B_o - b'$

E -- Modulus of Elasticity

I -- Moment of Inertia

EI -- Bending Modulus

K -- A function of d/b = $\frac{\sigma_{cr}}{E} \cdot \left(\frac{d}{t}\right)^2$

P -- Applied Load

P_i -- Critical Load for all Modes of Buckling

P_1 -- Critical Load for Primary Mode of Buckling

P_{cr} -- Critical Load as Determined by Experimentation

$W_n(x, y;P)$ -- Total Deflection due to all Modes of Buckling

$W_n(x, y;0)$ -- Initial Deflection due to all Modes of Buckling at No Load

β -- Modulus of Elastic Support

Θ -- Angle Measurement .

$\psi(x,y)$ -- Normal Function

τ -- Shearing Stress

σ -- Normal Stress

σ_{cr} -- Critical Buckling Stress = $\frac{Pcr}{bt}$

ν -- Poisson's Ratio

1. Introduction.

GENERAL DISCUSSION OF THE PHENOMENA AND THE EFFECTS

The problem of determining the stresses in an elastic plate under tension when the material is pierced by a circular hole is one of both theoretical interest and practical importance. Provided that the plate may be regarded as infinitely extended in two dimensions, the solution for a single hole is easily found and is well known. The presence of the hole leads to the occurrence of stresses equal to three times the tension at infinity, these maximum stresses occurring at the edge of the hole and on the diameter perpendicular to the direction of the applied tension. At the edge of the hole and on the diameter parallel to the direction of the applied tension a circumferential compressive stress occurs equal to the tension applied at infinity. For sheets of finite width, with a hole diameter equal to four-tenths of the width of the sheet, it has been found that this maximum stress is 3.74 times the applied stress, while the compressive stress has been found to be -1.44 times the applied stress. With a hole diameter equal to one-tenth of the width of the sheet, the maximum stress has been found to be 3.03 times the applied stress, while the compressive stress has been found to be -1.03 times the applied stress. (5)*

The presence of compressive stresses in a thin elastic sheet leads to the question of the condition under which buckling may occur. A search of the literature indicated that this question has not been investigated previously. (4) Accordingly, the investigation reported herein was undertaken for the purpose of experimentally determining the

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* Numbers in parentheses refer to bibliographical references found on page 36.

conditions under which buckling would take place in such an elastic sheet pierced in the center by a circular hole and subjected to uniaxial tension.

In this analysis, it was assumed that Southwell's method of determining critical buckling load would be valid for all diameters of holes and all plate thicknesses. This assumption proved to be not altogether valid, but sufficient valid data were obtained to give legitimate results. It was necessary to obtain sufficient data on the buckling deflection to determine the critical buckling load, prior to yielding of the sheet at the point of maximum stress.

With this value of critical buckling load, the buckling stress was calculated; and, using the relationship,

$$\frac{\sigma_{cr}}{E} = K_{(d/b)} \left(\frac{t}{d}\right)^2$$

where $K_{(d/b)}$ is a function of hole diameter to plate width, K was evaluated for all sheets. This final result was plotted with K versus d/b.

2. Theoretical Analysis.

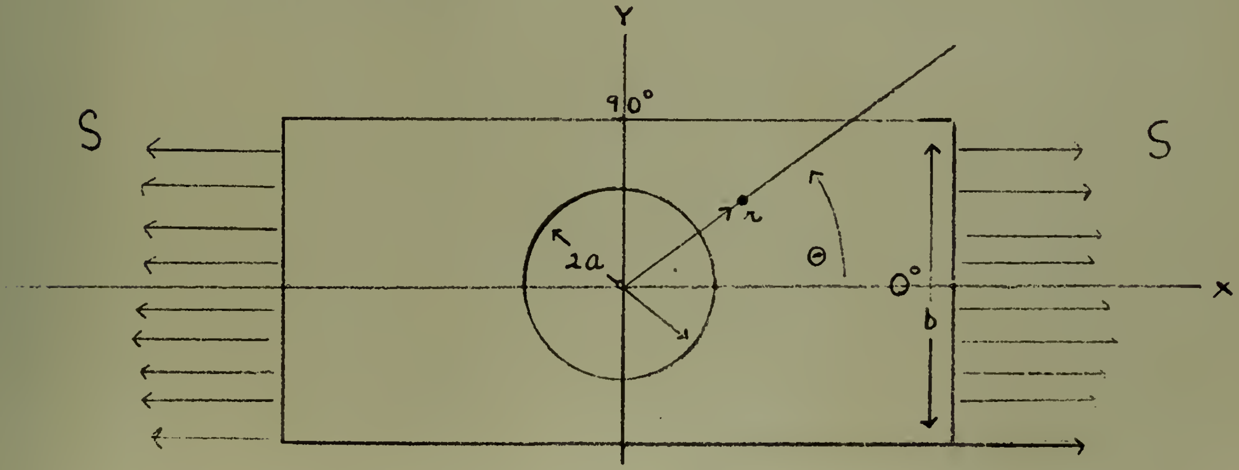


Figure 1

ME SHEET 5 RUN 1 2/22/57

LOAD P	$10^4/P$	B	ΔB	$10^4/ΔB$	$\frac{ΔB}{P}×10^4$	T	ΔT	STRESS	TIME	P	$10^4/B$	B	ΔB	$10^4/ΔB$	$\frac{ΔB}{P}×10^4$	T	ΔT	STRESS
0		791				~~1520~~			START 1000	3100		890	99		319			
100		792	1	~~100~~	100				815 1023	3200		892	101		316			
200		798	7	50	350	1500				3300		900	109		330			
300		800	10		~~333~~ 300					3400		904	113		332			
400		801	10		250					3500		908	117		334			
500		805	14		280				818 1022	3600		912	121		336			
600		803	12		200					3800		928	137		361			
800		815	24		300					4000		940	149		373			
1000		820	29		290													
1200		825	34		283													
1400		830	39		279													
1500		832	41		273													
1600		836	45		281													
1700		839	48		282													
1800		840	49		272													
1900		843	52		274				1010									
2000		849	58		290				852 1020									
2100		850	59		280				[illegible] 1027									
2200		852	61		277				858 1028									
2300		856	65		283													
2400		860	69		283													
2500		864	73		292													
2600		870	79		304													
2700		871	80		296													
2800		875	84		300													
2900		880	89		306													
3000		883	92		307													

1020

SHEET 5 RUN 1 EE

SHEET 5 RUN 1 24S-T3 16 X 36 X .040 WITH 4" HOLE

2/22

$\frac{\Delta B}{P}10^4$ vs ΔB

$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} = \frac{60}{313-265} \times 10^4 = \frac{600000}{48}$

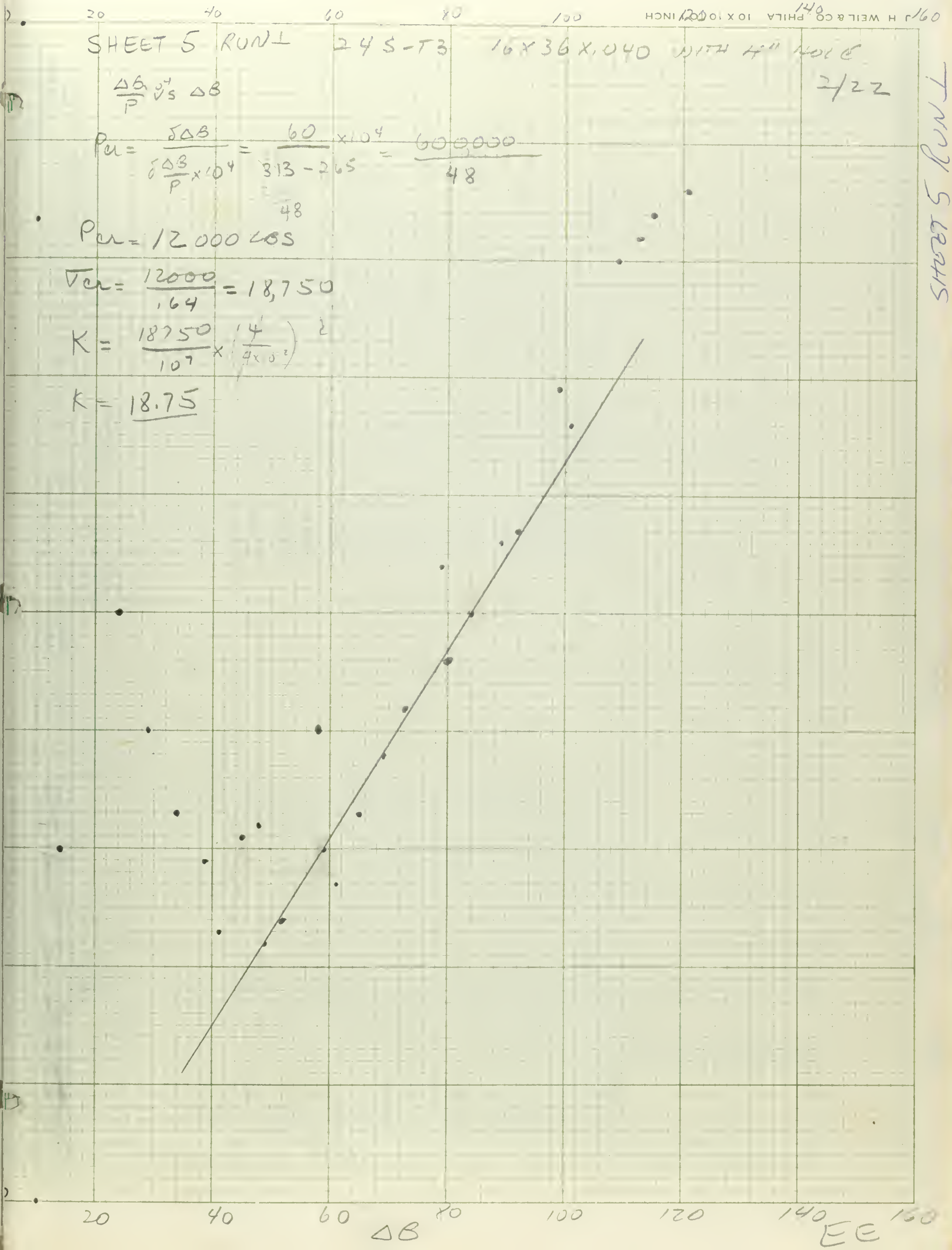
48

$P_{cr} = 12000$ LBS

$\sigma_{cr} = \frac{12000}{.64} = 18,750$

$K = \frac{18750}{10^7} \times \left(\frac{4}{4\times 10^{-2}}\right)^2$

$K = \underline{18.75}$



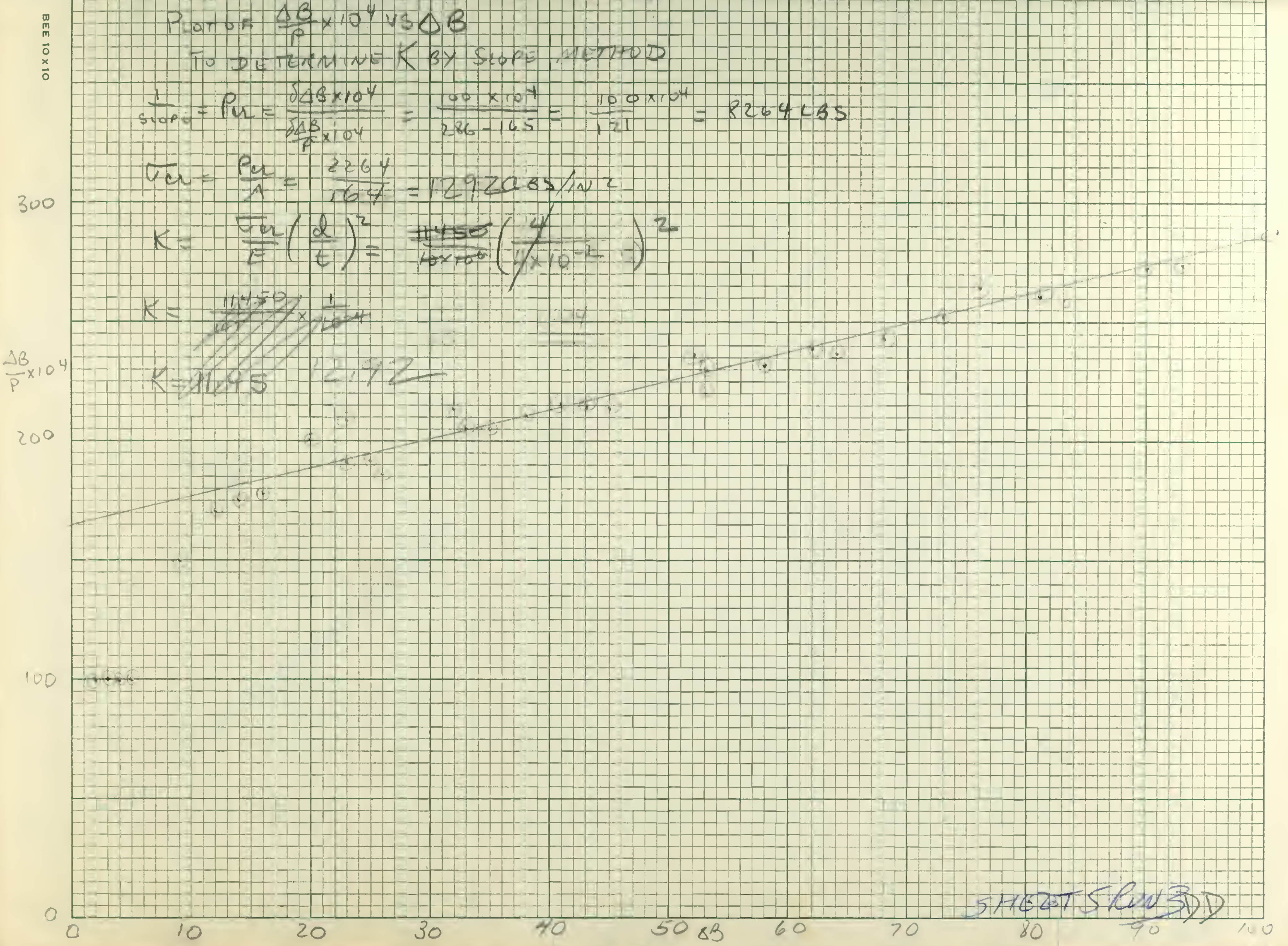
SHEET 5 RUN 1

EE

Σ SHEET 5 RUN 3 2/20/57

LOAD P	$10^4/P$	B	ΔB	$10^4/ΔB$	$ΔB \times 10^4/P$	T	ΔT	STRESS PSI.	TIME	LOAD P	$10^4/P$	B	ΔB	$10^4/ΔB$	$ΔB \times 10^4/P$	T	ΔT	STRESS PSI.
0		847.			—	1330			START 1424	2100	4.76	892	45	222	214	2012		
100	100	847	0	—	—				FINISH 1444	2200	4.54	899	52	192	236			
200	50	849	2	5000	100	1402			850-1382	2300	4.35	900	53	189	230			
300	33.3	850	3	3333	100					2400	4.16	900	53	189	221			
400	25.0	851	4	2500	100					2500	4.00	905	58	172	232			
500	20.0	852 855	5	2000	100	1505 1522				2600	4.84	909	62	161	238			
600	16.7	856	9	1111	150					2700	3.70	911	64	156	237			
700	14.3	859	12	833	171					2800	3.57	915	68	147	243	2238		
800	12.5	861	14	714	175					2900	3.44	920	73	136	252			
900	11.1	863	16	625	178					3000	3.33	923	76	132	253			
1000	10.0	867	20	500	200	1675				3100	3.23	928	81	123	261	2330		
1100	9.09	870	23	435	209					3200	3.13	930	83	120	259			
1200	8.33	870	23	435	191					3300	3.03	937	90	111	273			
1300	7.69	872	25	400	192					3400	2.94	940	93	108	274			
1400	7.14	873	26	385	186					3500	2.86	948	101	99.0	288			
1500	6.67	879	32	313	213	1830				3600	2.78	950	103	97.0	286			
1600	6.24	880	33	303	206					3700	2.70	958	111	90.1	300	2520		
1700	5.88	882	35	286	205					3800	2.63	962	115	87.0	303			
1800	6.56	885	38	263	211					3900	2.56	970	123	81.3	315			
1900	5.76	888	41	244	216					4000	2.50	978	131	76.3	328	2610		
2000	5.00	890	43	233	215													

SHEET 5 RUN 3



PLOT OF $\frac{\Delta B}{P} \times 10^4$ VS ΔB

TO DETERMINE K BY SLOPE METHOD

$$\frac{1}{\text{slope}} = P_{cr} = \frac{\delta \Delta B \times 10^4}{\delta \frac{\Delta B}{P} \times 10^4} = \frac{100 \times 10^4}{286 - 165} = \frac{100 \times 10^4}{121} = 8264 \text{ LBS}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{8264}{.64} = 12912 \text{ LBS/IN}^2$$

$$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \cancel{\frac{11450}{10 \times 10^6}}\left(\cancel{\frac{4}{1.4 \times 10^{-2}}}\right)^2$$

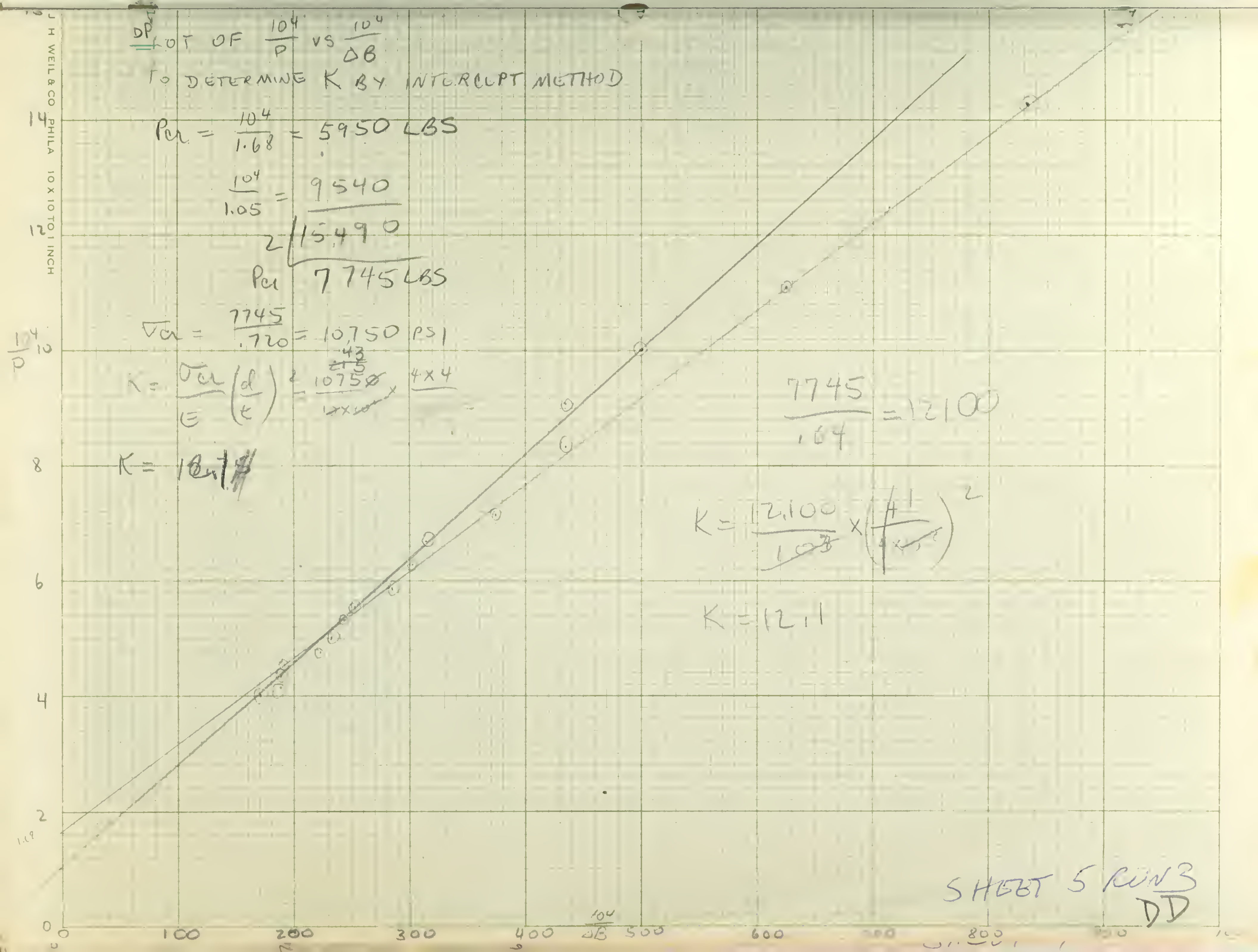
$$K = \cancel{\frac{11450}{10^7}} \times \cancel{\frac{1}{10^{-4}}}$$

~~K = 11.45~~ 12.92

DP

PLOT OF $\frac{10^4}{P}$ VS $\frac{10^4}{\Delta B}$

TO DETERMINE K BY INTERCEPT METHOD



$P_{cr} = \frac{10^4}{1.68} = 5950$ LBS

$\frac{10^4}{1.05} = 9540$

$2\overline{)15490}$

P_{cr} 7745 LBS

$\sigma_{cr} = \frac{7745}{.720} = 10,750$ PSI

$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \frac{\overset{43}{\cancel{215}}}{\cancel{10750}} \quad \frac{4 \times 4}{}$

K = 10.7

$\frac{7745}{.64} = 12100$

$K = \frac{12,100}{\cancel{10^3}} \times \left(\frac{4}{\cancel{4 \times}}\right)^2$

K = 12.1

SHEET 5 RUN 3

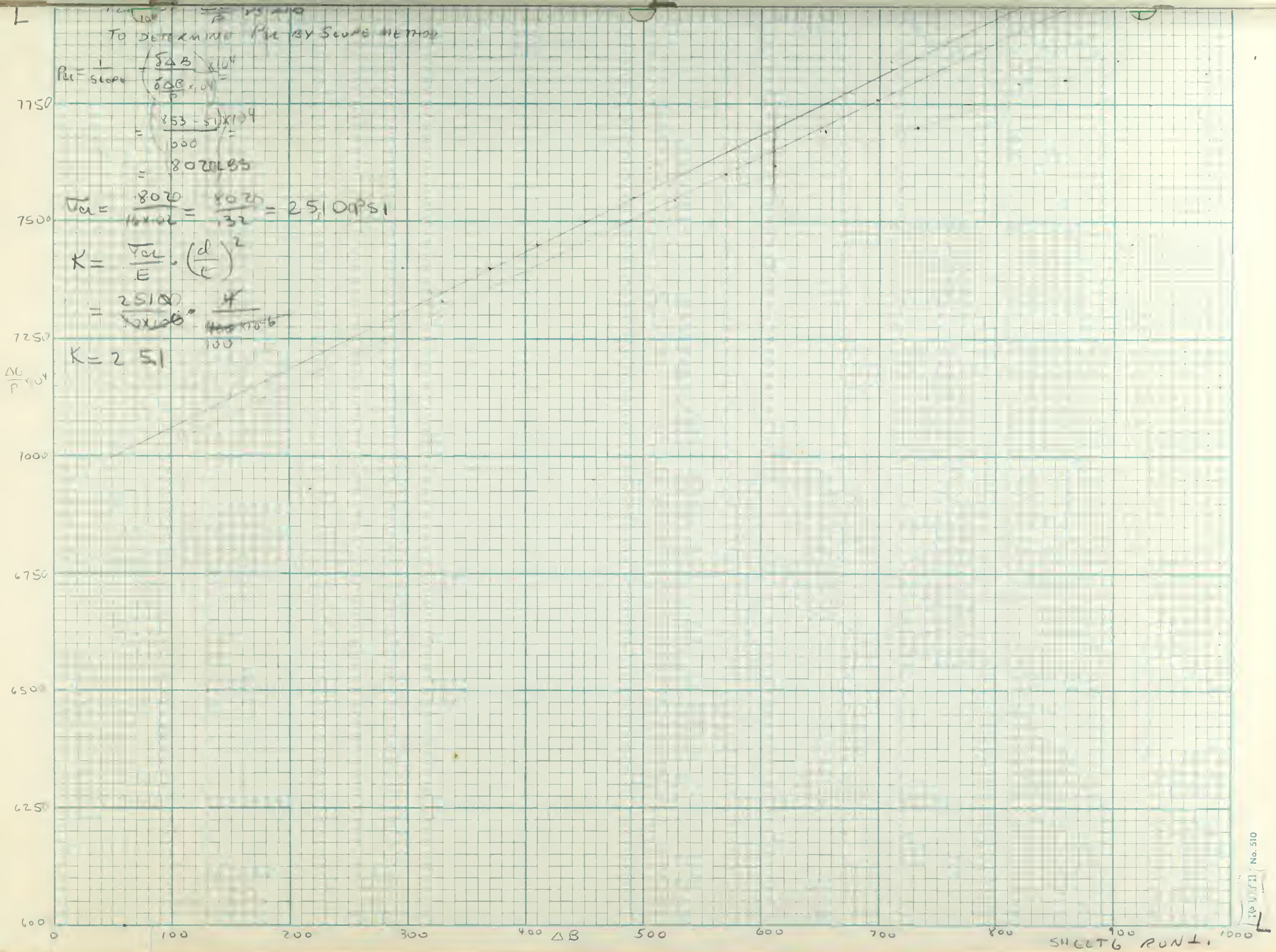
DD

LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B \times 10^4}{P}$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
0		750		—	—	110		
100	100	810	60	6000	166.7	708	2	
200	50.0	880	130	6500	76.9	692	18	
300	33.3	958	208	6930	48.1	680	30	
400	25.0	1046	296	7400	33.8	666	44	
450	22.2	1080	330	7330	30.3	660	50	
500	20.00	1120	370	7400	27.0	652	58	
550	18.2	1160	410	7450	24.4	646	64	
600	16.7	1200	450	7500	22.2	638	72	
650	15.4	1241	491	7550	20.4	632	78	
700	14.3	1278	528	7540	18.9	624	86	
750	13.3	1320	570	7600	17.5	618	92	
800	12.50	1361	611	7640	16.4	610	100	
850	11.8	1404	654	7690	15.3	600	110	
900	11.1	1448	698	7760	14.3	592	118	
950	10.5	1482	732	7700	13.7	585	125	
1000	10	1525	775	7750	12.9	578	132	
1050	9.52	1568	818	7790	12.2	570	140	
1100	9.09	1608	858	7800	11.6	562		
1150	8.70	1652	902	7840	11.1	554		
1200	8.33	1680	930	7750	10.8	549		
1250	8.00	1728	978	7820	10.2	545		
1300	7.69	1770	1020	7850	9.8	538		
1350	7.41	1812	1062	7860	9.4	530		
1400								
1450								

LOAD P	$10^4/P$	B	ΔB	$\frac{\Delta B \times 10^4}{P}$	$\frac{10^4}{B}$	T	ΔT	STRESS
1500								
1550								
1600								

RP-450

SHEET6 RUN 1. L



TO DETERMINE P_{cr} BY SLOPE METHOD

$$P_{cr} = \frac{1}{\text{SLOPE}} = \left(\frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4}\right) \times 10^4 =$$

$$= \left(\frac{853 - 51}{1000}\right) \times 10^4 =$$

$$= 8020 \text{ LBS}$$

$$\sigma_{cr} = \frac{8020}{16 \times .02} = \frac{8020}{.32} = 25{,}100 \text{ PSI}$$

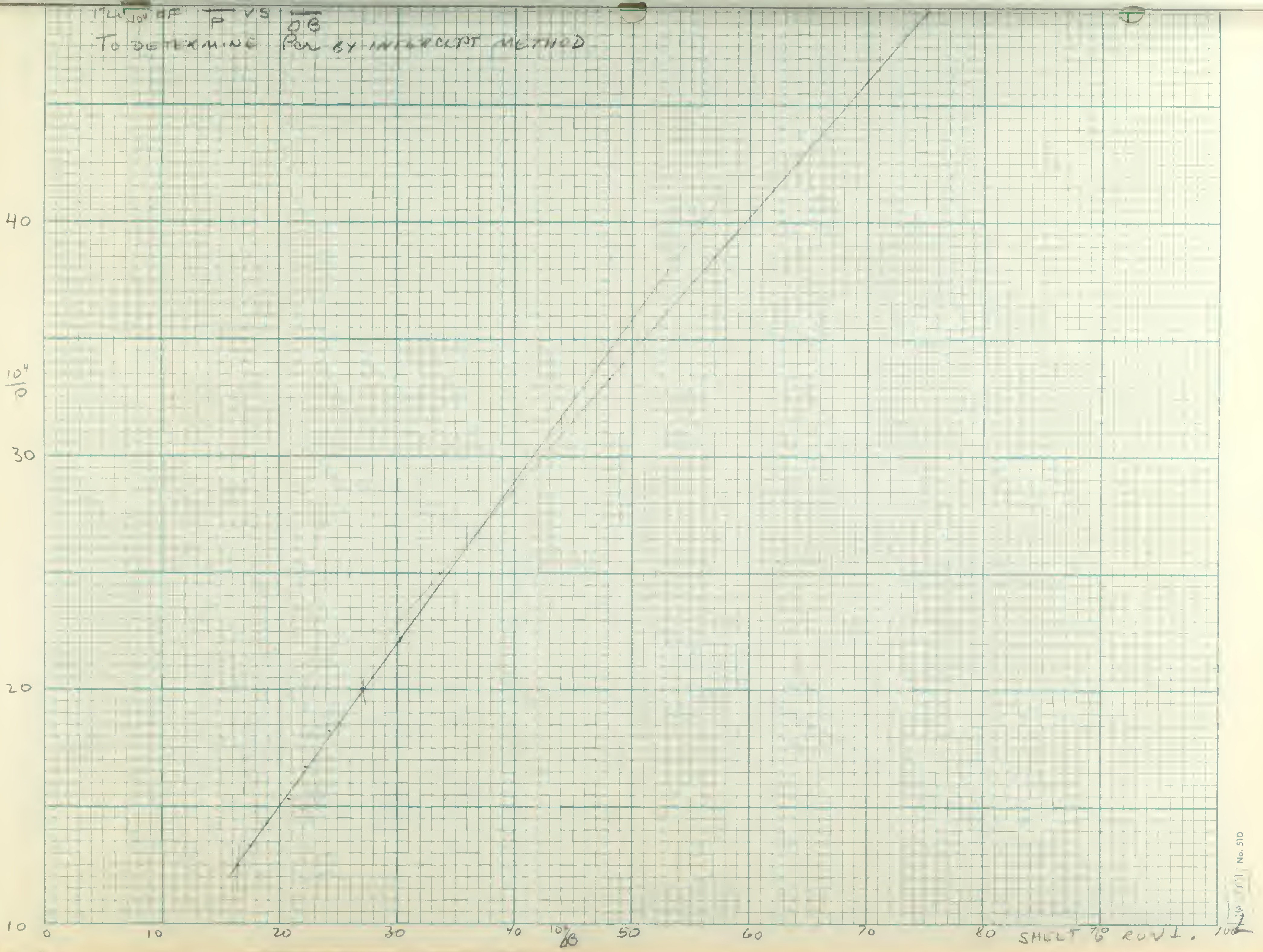
$$K = \frac{\sigma_{cr}}{E} \cdot \left(\frac{d}{t}\right)^2$$

$$= \frac{25100}{10 \times 10^6} \cdot \frac{4}{\cancel{400 \times 10^{-6}}\ 100}$$

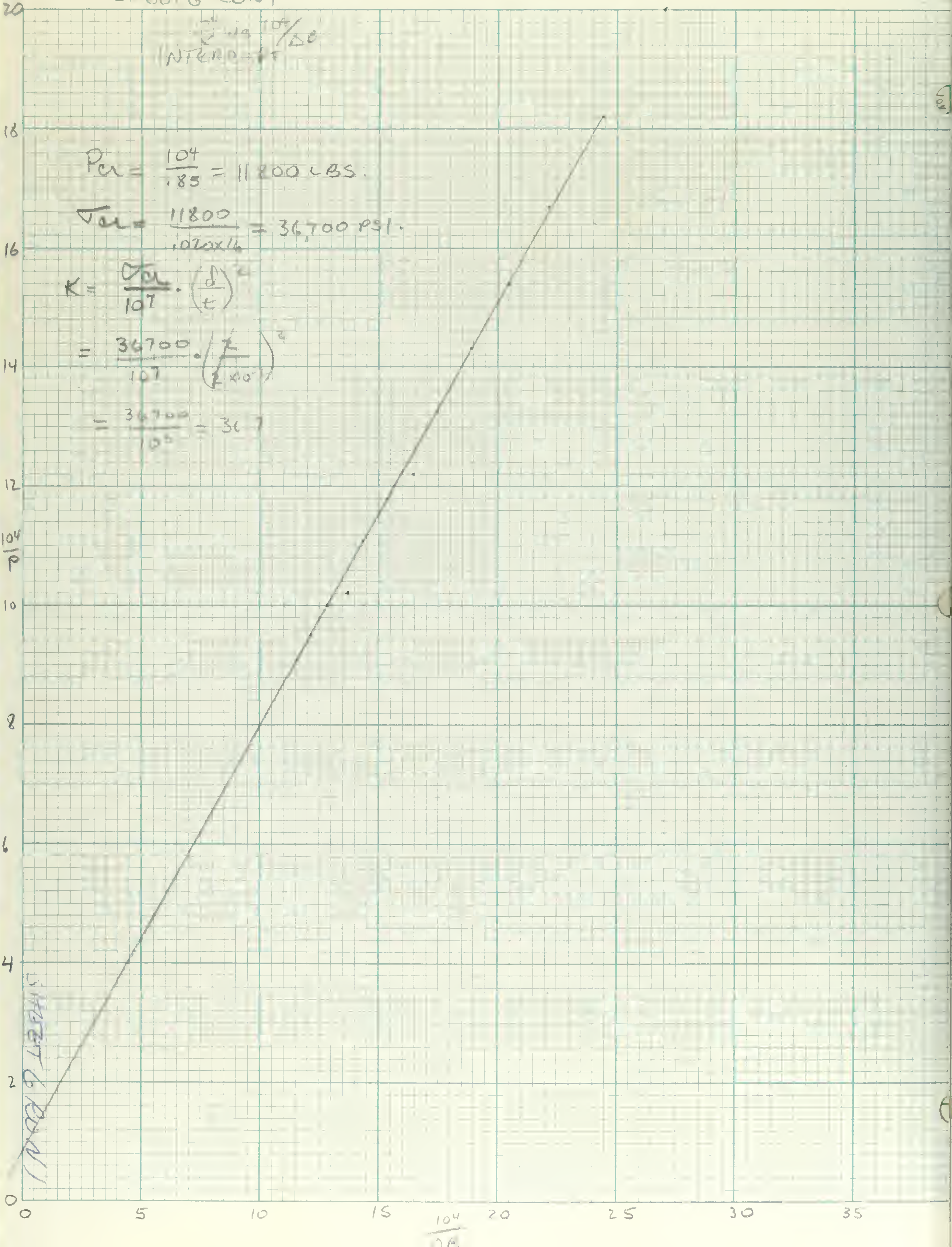
$$K = 2\ 51$$

SHEET 6 RUN 1.

No. 510


PLOT OF $\overline{P}$ VS $\overline{\phi\theta}$
TO DETERMINE P_{cr} BY INTERCEPT METHOD
$\frac{10^4}{P}$
40
30
20
10
0
10
20
30
40
$\frac{10^4}{\phi\theta}$
50
60
70
80
100
SHEET 7/6 RUN I.
No. 510

SHEET 6 RUN 1



$P_{cr} = \frac{10^4}{.85} = 11800$ LBS.

$\sigma_{cr} = \frac{11800}{.020 \times 16} = 36{,}700$ PSI.

$K = \frac{\sigma_{cr}}{10^7} \cdot \left(\frac{d}{t}\right)^2$

$= \frac{36700}{10^7} \cdot \left(\frac{2}{2 \times 10^{-2}}\right)^2$

$= \frac{36700}{10^3} = 36.7$

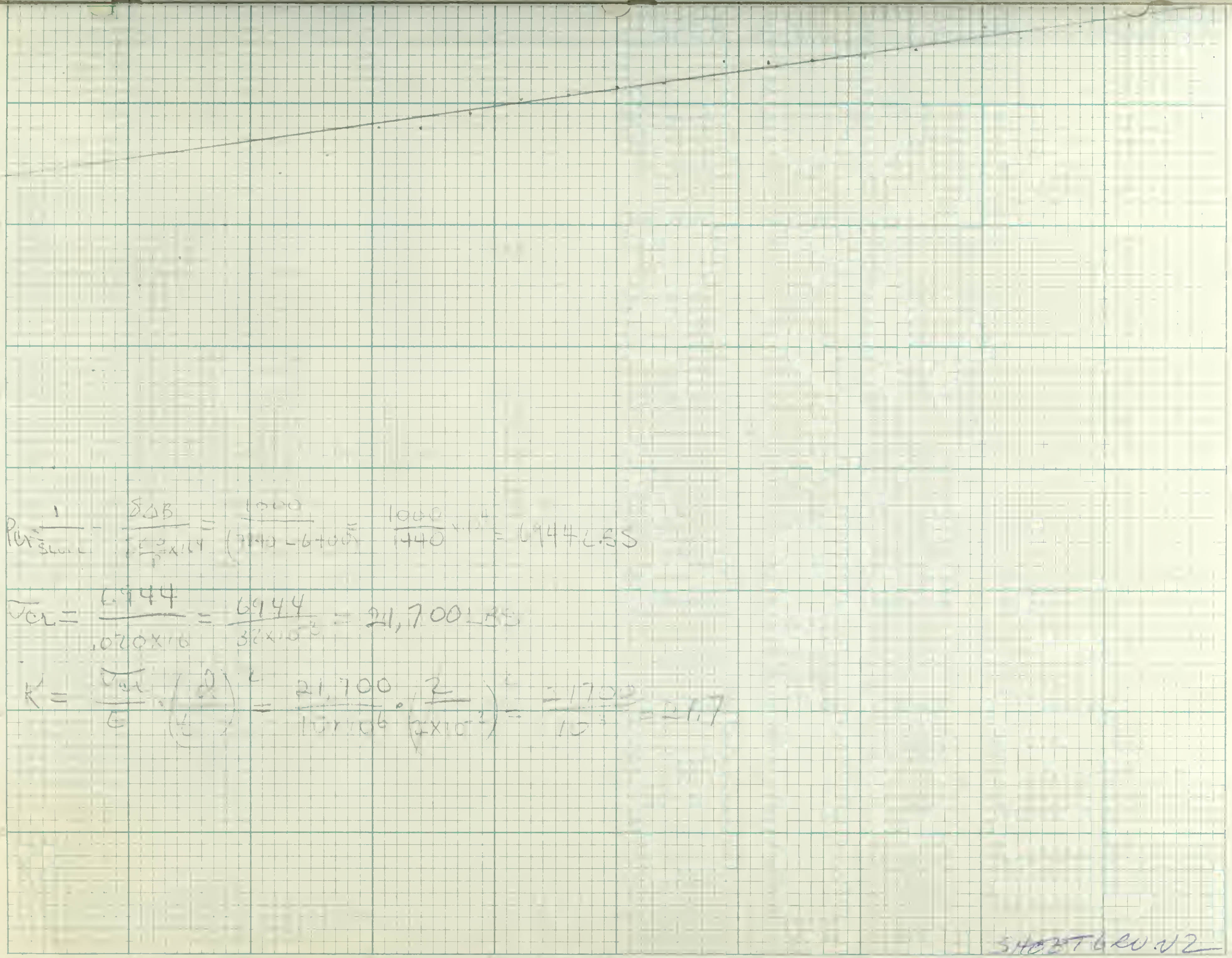
LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P} \times 10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
0		620				760		
50		632	12	2400		763		
100		660	40	4000		758		
150		692	72	4800		750		
200		730	110	5500		742		
250		763	143	5720		733		
300		800	180	6000		724		
350		845	225	6430		715		
400		883	263	6580		708		
450		926	306	6800		700		
500		960	340	6800		692		
550		1000	380	6910		680		
600		1042	422	7030		671		
650		1080	460	7080		663		
700		1120	500	7140		653		
750		1158	538	7170		648		
800		1208	588	7350		633		
850		1244	624	7340		623		
900		1282	662	7360		612		
950		1322	702	7390		[illegible]		
1000		1365	745	7450		[illegible]		
1050		1421	801	7630		591		
1100		1451	832	7560		582		
1150		1500	880	7650		572		
1200		1540	920	7670		562		
1250								

LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P} \times 10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
1300								

RP-450

SHEET 6 RUN 2 M.

M



$P_{CR} = \frac{1}{SLOPE} = \frac{\delta\Delta B}{\frac{\Delta\delta}{P}\times 10^{4}} = \frac{1000}{(7440-6000)} = \frac{1000}{1440}\times 10^{4} = 6944\ LBS$

$\sigma_{CR} = \frac{6944}{.020\times 16} = \frac{6944}{32\times 10^{-2}} = 21{,}700\ LBS$

$K' = \frac{\sigma_{cr}}{E}\cdot\left(\frac{b}{t}\right)^{2} = \frac{21{,}700}{10\times 10^{6}}\cdot\left(\frac{2}{2\times 10^{-2}}\right)^{2} = \frac{21700}{10^{3}} = 21.7$

SHEET 6 REV. 2

M

No. 510

LOAD P	$10^4/P$	B	ΔB	$\frac{\Delta B \times 10^4}{P}$	$10^4/B$	T	ΔT	STRESS
0		620	–					
50		638	18	3600		765		
100		663	43	4300		760		
150		690	70	4670		753		
200		728	108	5400		746		
250		763	143	5720		738		
300		800	180	6000		730		
350		842	222	6340		718		
400		880	260	6500		710		
450		922	302	6711		702		
500		960	340	6800		690		
550		1000	380	6909		684		
600		1043	423	7050		673		
650		1084	464	7138		668		
700		1122	502	7171		658		
750		1158	538	7173		648		
800		1199	579	7238		638		
850		1244	624	7341		628		
900		1285	665	7389		622		
950		1328	708	7453		610		
1000		1380	760	7600		600		
1050		1412	792	7543		590		
1100		1455	835	7590		580		
1150		1510	810	7740		570		
1200		1550	930	7750		560		

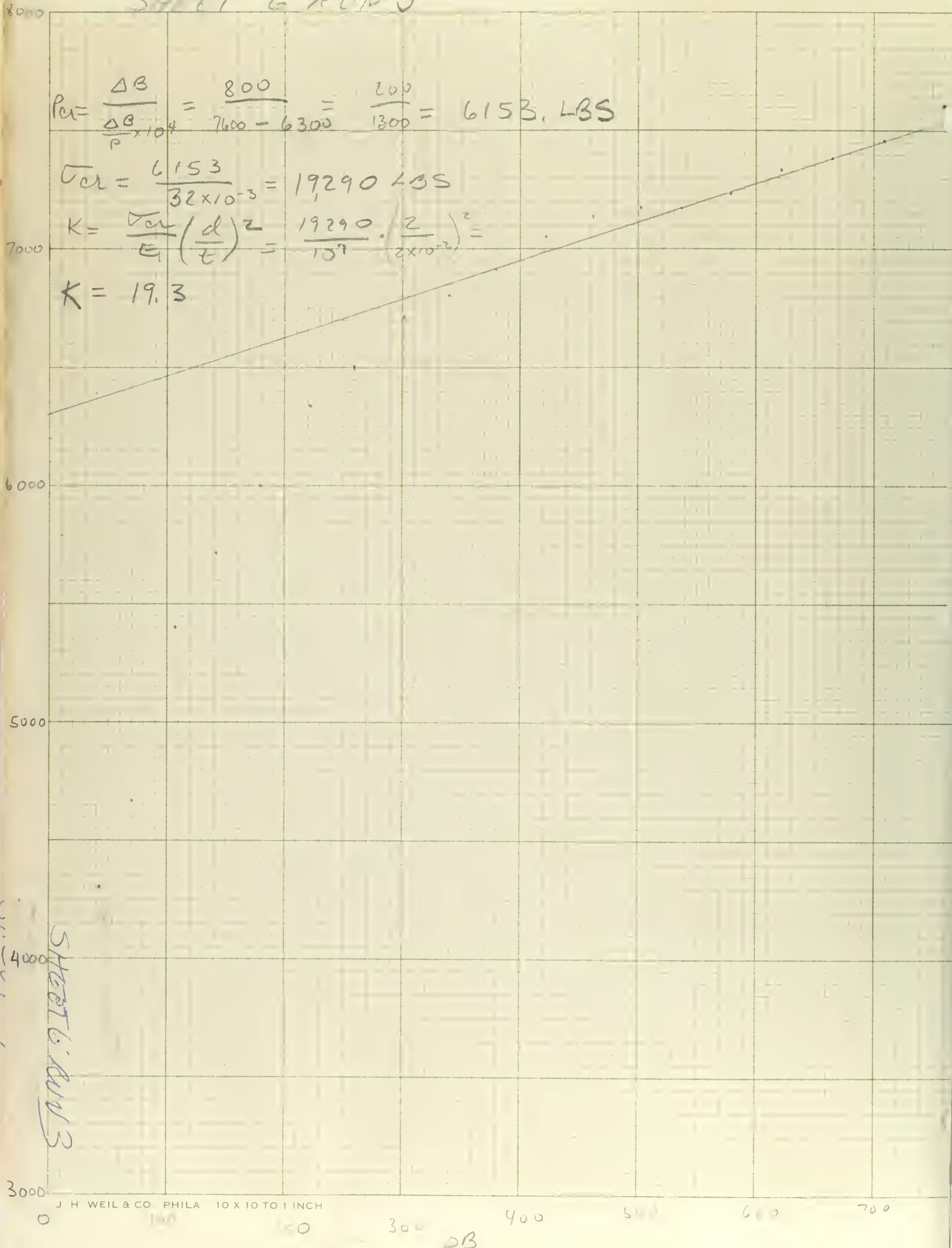
LOAD P	$10^4/P$	B	ΔB	$\frac{\Delta B \times 10^4}{P}$	$10^4/\Delta B$	T	ΔT	STRESS
1300		1622	1002	7708				
1400		1700	1080	7714				
1500		1790	1170	7800				

RP-450

SHEET 6 RUN 3

N

SHEET 6 RUN 3



$P_{cr} = \frac{\Delta B}{\frac{\Delta B}{P} \times 10^4} = \frac{800}{7600 - 6300} = \frac{800}{1300} = 6153.$ LBS

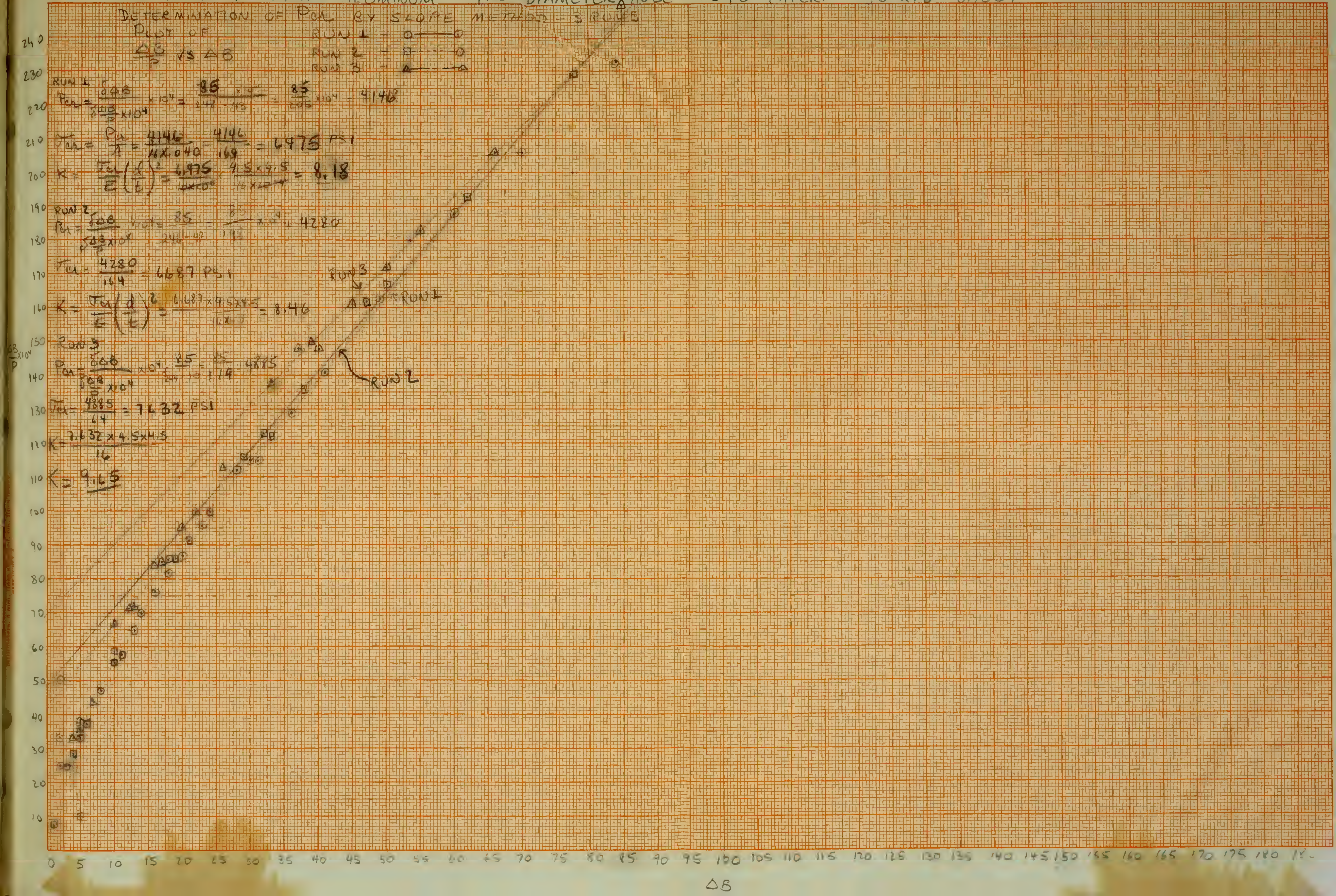
$\sigma_{cr} = \frac{6153}{32 \times 10^{-3}} = 19{,}290$ LBS

$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \frac{19290}{10^7} \cdot \left(\frac{2}{2 \times 10^{-2}}\right)^2 =$

$K = 19.3$

J H WEIL & CO PHILA 10 X 10 TO 1 INCH

SHEET NUMBER 7 24 ST3 ALUMINUM 4.5" DIAMETER HOLE .040" THICK. 36"x16" SHEET



RUN 1

$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} \times 10^4 = \frac{85 \times 10^4}{248 - 43} = \frac{85}{205} \times 10^4 = 4146$

$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{4146}{16 \times .040} = \frac{4146}{.64} = 6475$ PSI

$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \frac{6475}{10 \times 10^6} \times \frac{4.5 \times 4.5}{16 \times 10^{-4}} = 8.18$

RUN 2

$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} \times 10^4 = \frac{85}{248 - 48} = \frac{85}{199} \times 10^4 = 4280$

$\sigma_{cr} = \frac{4280}{.64} = 6687$ PSI

$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \frac{6.687 \times 4.5 \times 4.5}{16 \times 10} = 8.46$

RUN 3

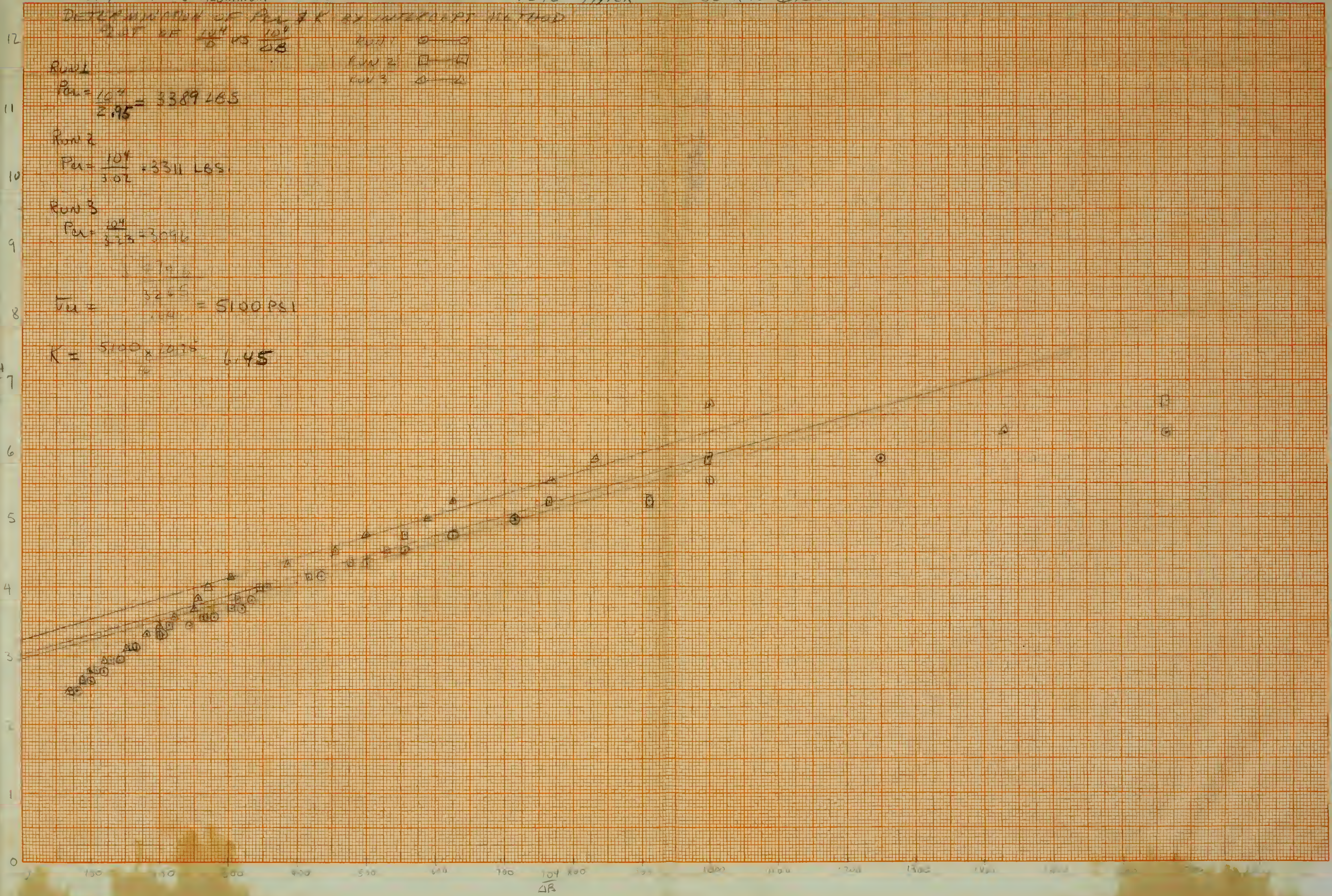
$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} \times 10^4 = \frac{85}{248 - 74} = \frac{85}{174} = 4885$

$\sigma_{cr} = \frac{4885}{.64} = 7632$ PSI

$K = \frac{7.632 \times 4.5 \times 4.5}{16}$

$K = 9.65$

SHEET 7 24ST3 ALUMINUM 4.5" DIAMETER HOLE .040" THICK 36"x16" SHEET.


DETERMINATION OF P_{cr} & K BY INTERCEPT METHOD

PLOT OF $\frac{10^4}{P}$ VS $\frac{10^4}{\Delta B}$

RUN 1

$P_{cr} = \frac{10^4}{2.95} = 3389$ LBS

RUN 2

$P_{cr} = \frac{10^4}{3.02} = 3311$ LBS.

RUN 3

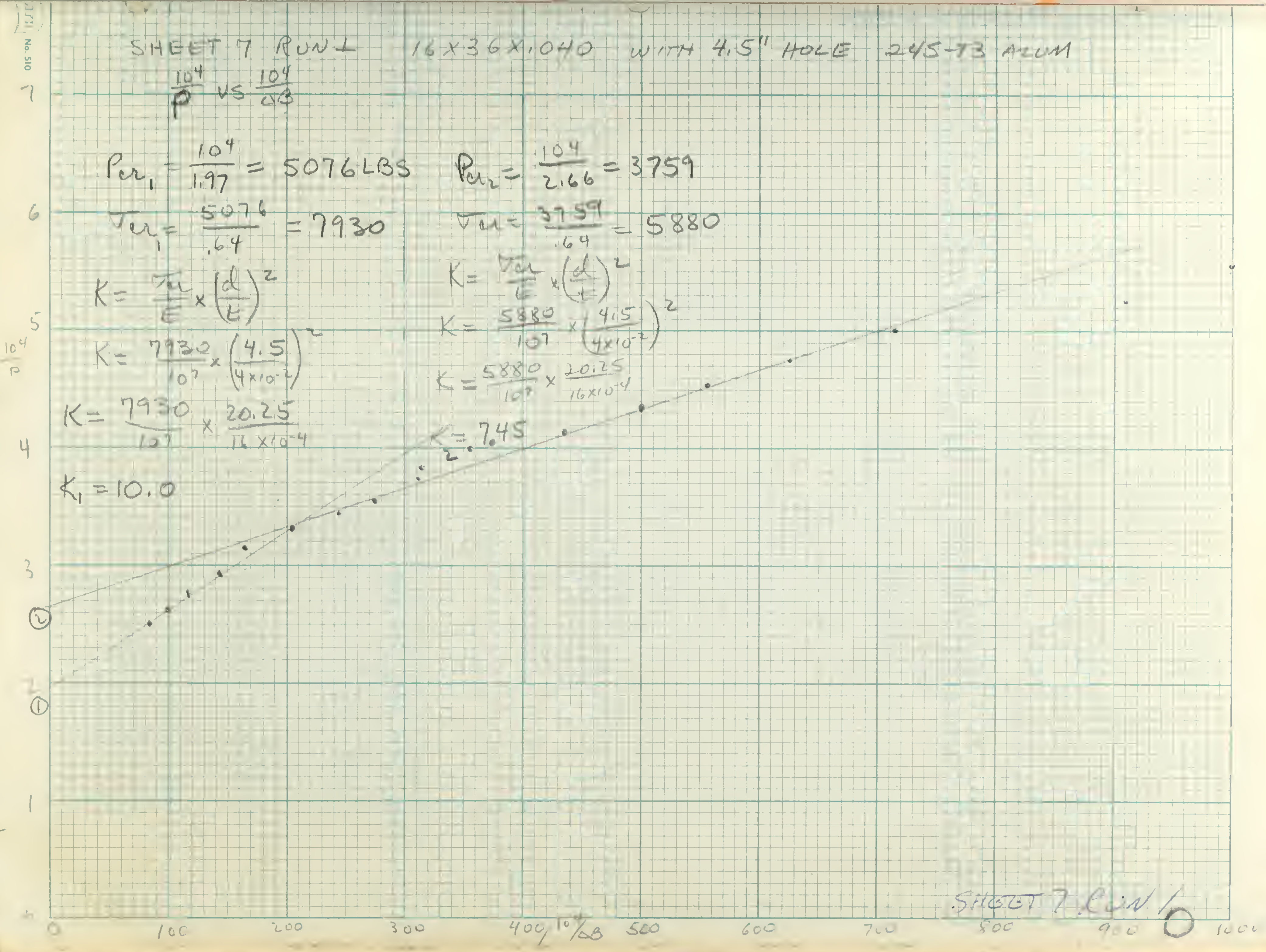
$P_{cr} = \frac{10^4}{3.23} = 3096$

$\sigma_u = \frac{3265}{.64} = 5100$ PSI

K = $\frac{5100 \times 10^{..}}{..}$ 6.45

SHEET 7 RUN 1 16X36X.040 WITH 4.5" HOLE 24S-T3 ALUM

$\frac{10^4}{P}$ VS $\frac{10^4}{\delta}$



$P_{cr_1} = \frac{10^4}{1.97} = 5076$ LBS

$\sigma_{cr_1} = \frac{5076}{.64} = 7930$

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{d}{t}\right)^2$

$K = \frac{7930}{10^7} \times \left(\frac{4.5}{4 \times 10^{-2}}\right)^2$

$K = \frac{7930}{10^7} \times \frac{20.25}{16 \times 10^{-4}}$

$K_1 = 10.0$

$P_{cr_2} = \frac{10^4}{2.66} = 3759$

$\sigma_{cr_2} = \frac{3759}{.64} = 5880$

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{d}{t}\right)^2$

$K = \frac{5880}{10^7} \times \left(\frac{4.5}{4 \times 10^{-2}}\right)^2$

$K = \frac{5880}{10^7} \times \frac{20.25}{16 \times 10^{-4}}$

$K_2 = 7.45$

SHEET 7 RUN 1

P	$10^4/P$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS PSI
0	—	1081	0					
100	100	1081	0					
200	50	1081	0					
300	33.3	1081	0					
400	25.0	1081	0					
500	20.0	1081	0					
600	16.7	1081	0					
700	14.3	1081	0					
800	12.5	1081	0					
900	11.1	1081	0					
1000	10.0	1081	0					
1100	9.09	1081	0					
1200	8.33	1084	3	3333	25			
1300	7.69	1082	1	10000	7.69			
1400	7.14	1086	5	2000	35.7			
1500	6.67	1086	5	2000	33.3			
1600	6.24	1087	6	1667	37.5			
1700	5.88	1089	8	1250	47.1			
1800	5.56	1091	10	1000	55.6			
1900	5.26	1092	11	909	57.9			
2000	5.00	1095	14	714	70.0			
2100	4.76	1097	16	625	76.2			
2200	4.54	1099	18	556	81.8			
2300	4.35	1101	20	500	87.0			
2400	4.16	1104	23	435	95.8			
2500	4.00	1109	28	357	112			

P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS PSI
2600	3.84	1111	30	333	115			
2700	3.70	1112	31	323	115			
2800	3.57	1117	36	278	129			
2900	3.45	1122	41	244	141			
3000	3.33	1129	49	204	163			
3200	3.13	1140	60	167	188			
3400	2.94	1150	70	143	206			
3600	2.78	1164	84	119	233			
3800	2.63	1181	100	100	263			
4000	2.50	1205	124	80.6	310			
		1081 4						

RP-950

SHEET 7 RUN 1

0

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SHEET 7 RUN 1. 16 x 36 x .040" WITH 4.5" HOLE 24 ST 3 ALUMINUM

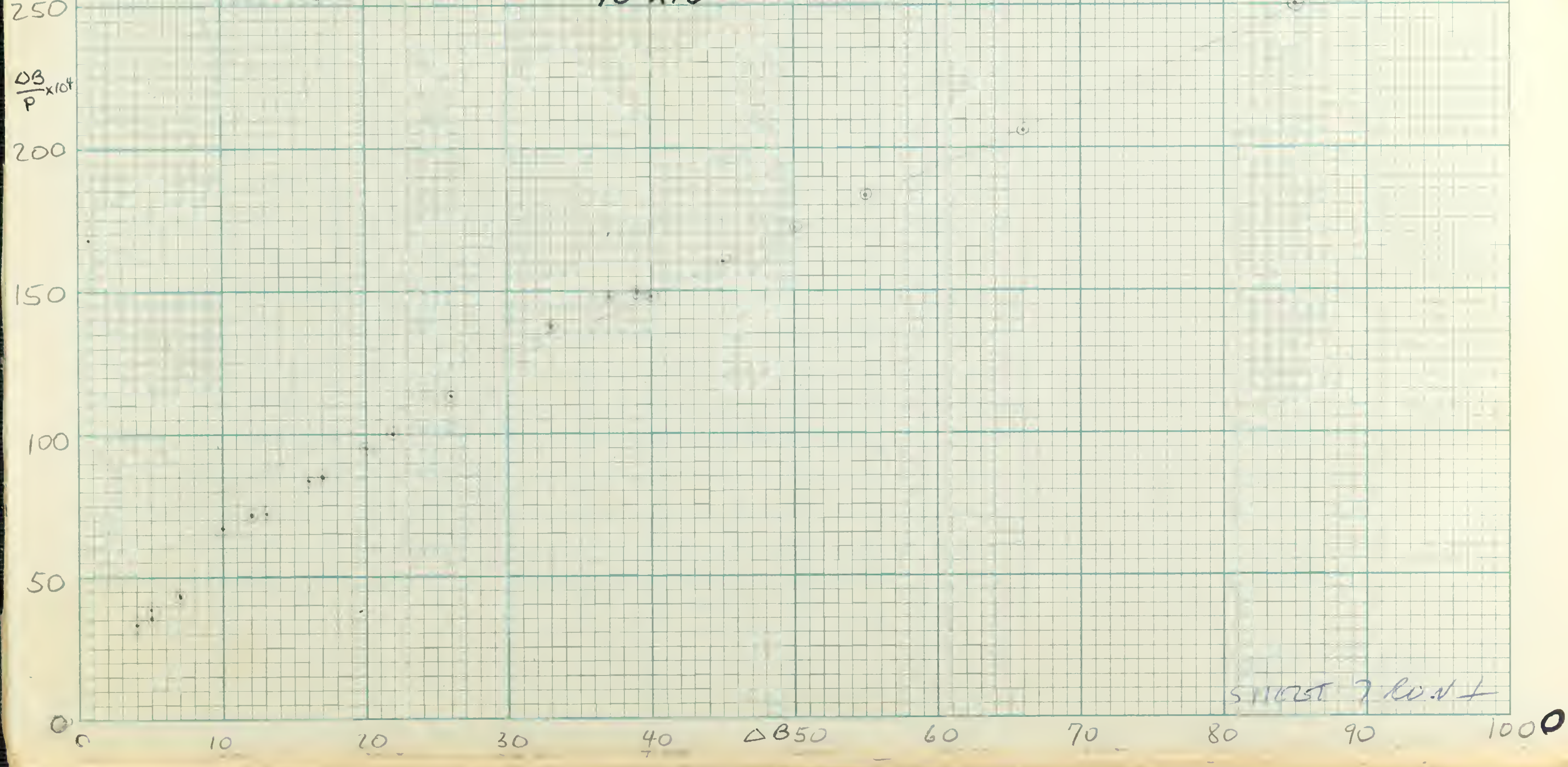
PLOT OF $\frac{\Delta B}{P} \times 10^4$ VS ΔB

TO DETERMINE K BY SLOPE METHOD

$$P_{cr} = \frac{1}{\text{SLOPE}} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} \times 10^4 = \frac{100}{283-58} = \frac{100}{225} \times 10^4 = 4444 \text{ LBS}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{4444}{16 \times .040} = \frac{111.1}{.16} = 7000 \text{ LBS/IN}^2$$

$$K = \frac{\sigma_{cr}}{E}\left(\frac{\delta}{t}\right)^2 = \frac{7000}{10 \times 10^6} \cdot \frac{4.5 \times 4.5}{16 \times 10^{-4}} = 8.86\cancel{87}$$



P	$\frac{10^4}{P}$	B	ΔB	$10^4/\Delta B$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS
0		1090	0					
100	100	1090	0					
200	50	1090	0		–			
300	33.3	1090	0		–			
400	25	1092	2		50			
500	20	1095	5		10			
600	16.7	1092	2		33.3			
700	14.3	1090	0		–			
800	12.5	1092	2		25			
900	11.1	1090	0	–	–			
1000	10.0	1092	2		20			
1100	9.09	1090	0	–	–			
1200	8.33	1090	0	–	–			
1300	7.69	1091	1	10000	7.69			
1400	7.14	1094	4	2500	28.6			
1500	6.67	1095	5	2000	33.3			
1600	6.24	1096	6	1670	37.5			
1700	5.88	1100	10	1000	58.8			
1800	5.56	1100	10	1000	55.6			
1900	5.26	1101	11	909	57.9			
2000	5.00	1103	13	769	65.0			
2100	4.76	1108	18	556	85.7			
2200	4.54	1109	19	526	86.4			
2300	4.35	1111	21	476	91.3			
2400	4.16	1114	24	416	100			
2500	4.00	1119	29	345	116			

P	$10^4/P$	B	ΔB	$10^4/\Delta B$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	VANIS STRESS
2600	3.84	1122	32	313	123			
2700	3.70	1123	33	303	122			
2800	3.57	1128	38	263	136			
2900	3.45	1137	47	213	162			
3000	3.33	1140	50	200	167			
3200	3.13	1152	62	161	193			
3400	2.94	1168	78	128	229			
3600	2.78	1182	92	109	255			
3800	2.63	1204	114	87.7	300			
4000	2.50	1230	140	71.4	350			

RP-450

SHEET 7 RUN 2 P

4/25/51

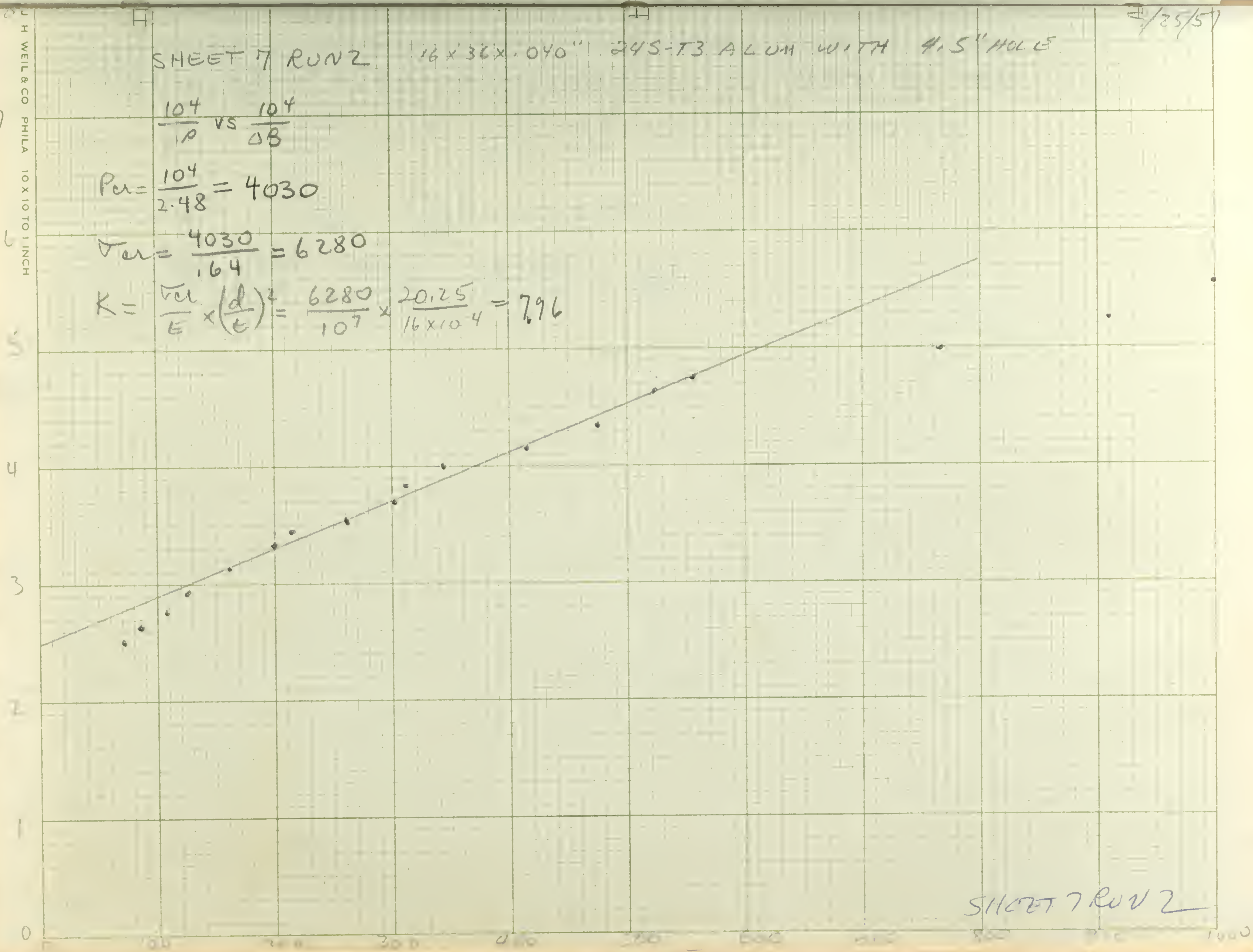
SHEET 7 RUN 2 16 x 36 x .040" 24S-T3 ALUM WITH 4.5" HOLE

$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta B}$

$P_{cr} = \frac{10^4}{2.48} = 4030$

$\sigma_{cr} = \frac{4030}{.164} = 6280$

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{d}{t}\right)^2 = \frac{6280}{10^7} \times \frac{20.25}{16 \times 10^{-4}} = 7.96$



SHEET 7 RUN 2

J H WEIL & CO PHILA 10 X 10 TO 1 INCH

3/25/57
DAVIS.

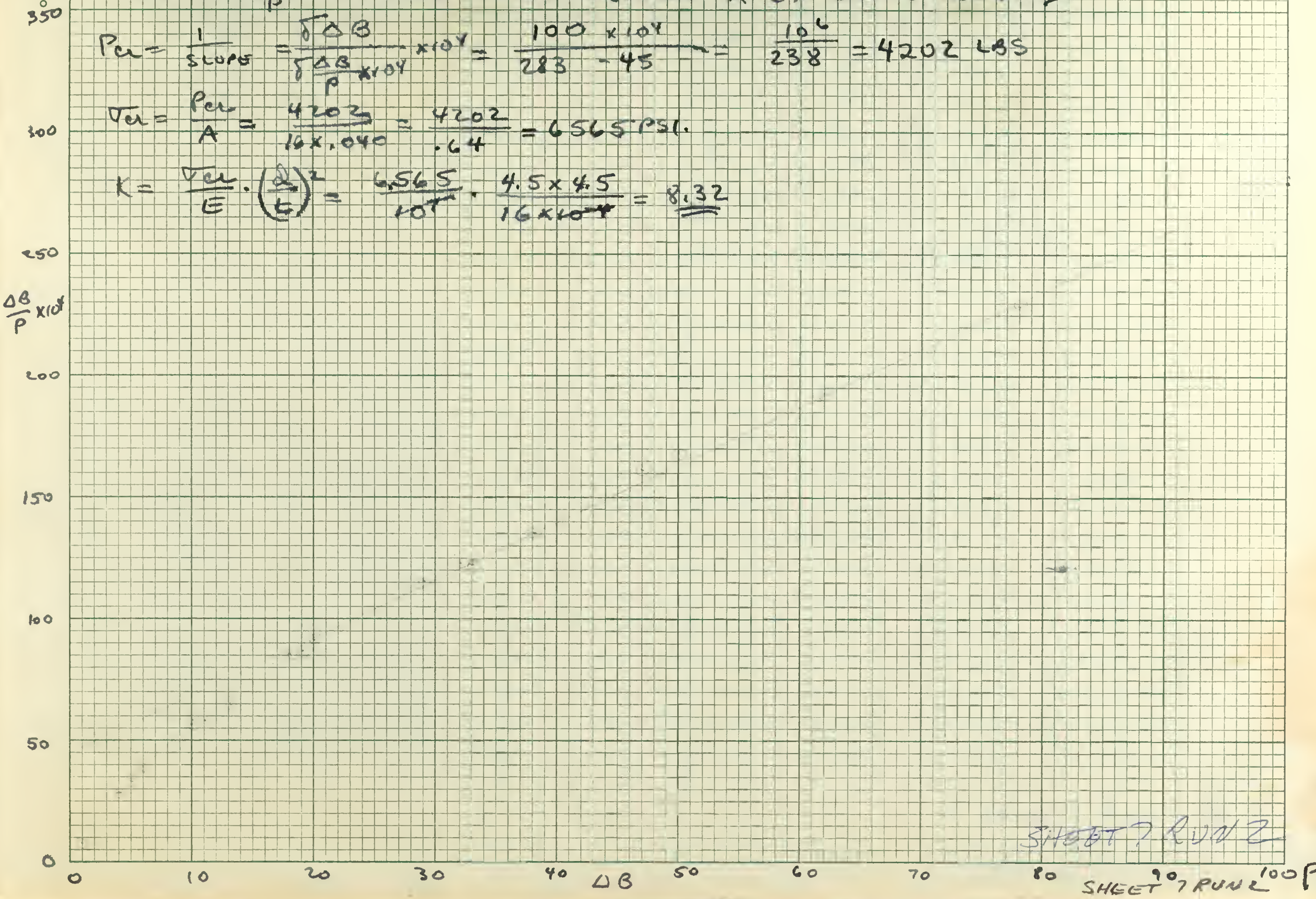
SHEET 7 RUN 2 16 × 36 × .040" 4.5" HOLE 24ST6 T3 ALUM

PLOT OF $\frac{\Delta B}{P} \times 10^4$ VS ΔB TO DETERMINE K BY SLOPE METHOD

$$P_{cr} = \frac{1}{\text{SLOPE}} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} \times 10^4 = \frac{100 \times 10^4}{283 - 45} = \frac{10^6}{238} = 4202 \text{ LBS}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{4202}{16 \times .040} = \frac{4202}{.64} = 6565 \text{ PSI.}$$

$$K = \frac{\sigma_{cr}}{E} \cdot \left(\frac{d}{t}\right)^2 = \frac{6565}{10^7} \cdot \frac{4.5 \times 4.5}{16 \times 10^{-4}} = \underline{\underline{8.32}}$$



P	$10^4/P$	R	ΔB	$10^4/\Delta B$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS PSI		P	$10^4/P$	B	ΔB	$10^4/\Delta B$	$\frac{\Delta B}{P} \times 10^4$	1	ΔT	STRESS
0	—	1095	0							2600	3.85	1134	39	256	150			
100	100	1098	3							2700	3.70	1135	40	250	148			
200	50	1100	5							2800	3.57	1140	45	222	161			
300	33.3	1098	3							2900	3.45	1145	50	200	172			
400	25.0	1099	4							3000	3.33	1150	55	182	183			
500	20.0	1098	3							3200	3.13	1161	66	152	206			
600	16.7	1100	5							3400	2.94	1180	85	118	250			
700	14.3	1100	5							3600	2.78	1196	101	99.1	281			
800	12.5	1100	5							3800	2.63	1216	121	82.6	318			
900	11.1	1098	3							4000	2.50	1240	145	69.0	363			
1000	10.0	1098	3	—														
1100	9.09	1095	0	—	—													
1200	8.33	1099	4	2500	33.3													
1300	7.69	1100	5	2000	38.5													
1400	7.14	1100	5	2000	35.7													
1500	6.66	1105	10	1000	66.7													
1600	6.25	1102	7	1429	43.8													
1700	5.88	1107	12	833	70.6													
1800	5.56	1108	13	769	72.2													
1900	5.26	1111	16	625	84.2													
2000	5.00	1112	17	588	85.0													
2100	4.76	1115	20	500	95.2													
2200	4.54	1117	22	454	100													
2300	4.35	1121	26	385	113													
2400	4.17	1128	33	303	138													
2500	4.00	1132	37	270	148													

RP-450

SHEET 7 RUN 3 Q

SHEET 7 RUN3

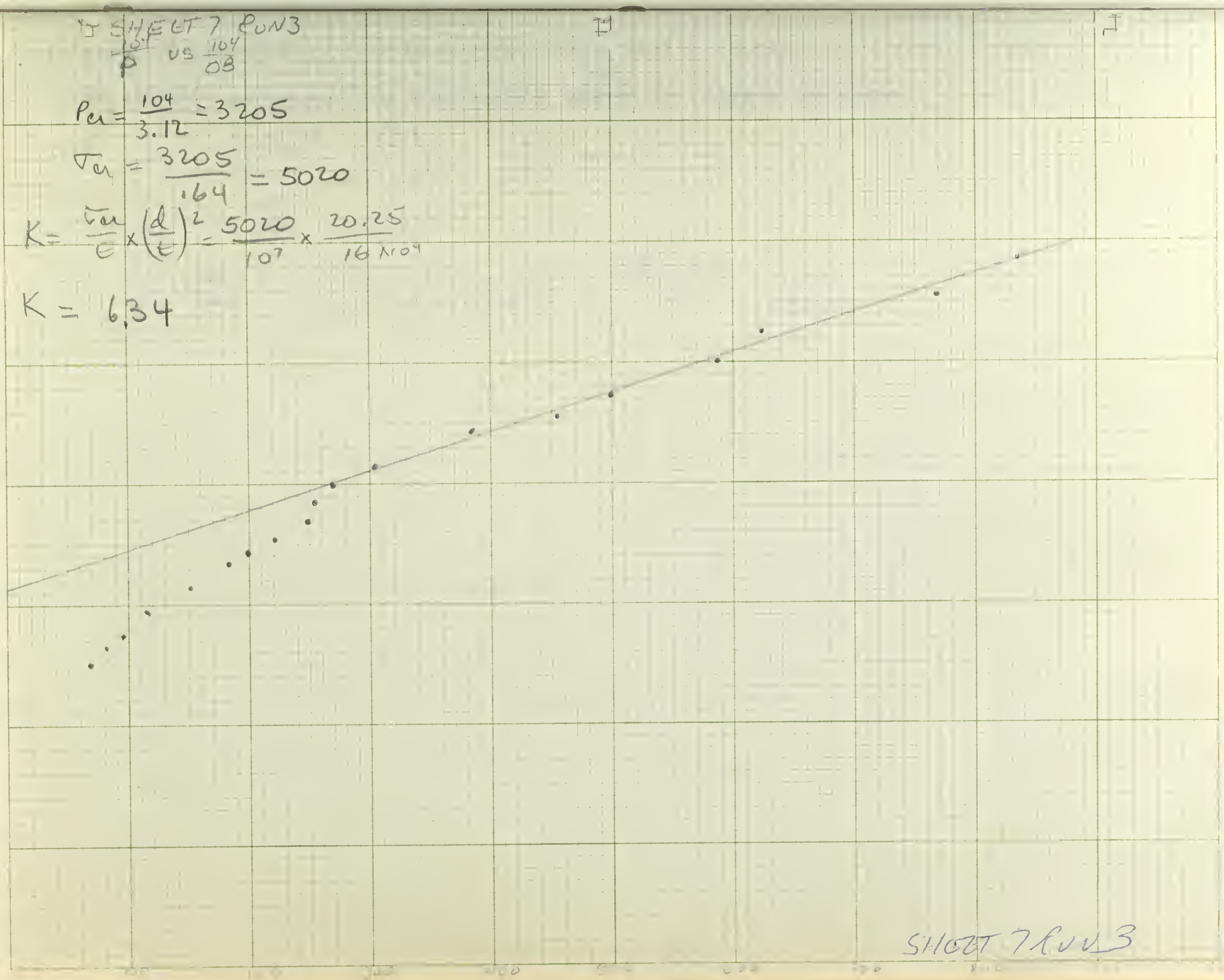
$\frac{10^4}{P}$ VS $\frac{10^4}{\sigma_B}$

$P_{cr} = \frac{10^4}{3.12} = 3205$

$\sigma_{cr} = \frac{3205}{.64} = 5020$

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{d}{t}\right)^2 = \frac{5020}{10^7} \times \frac{20.25}{16\times10^{4}}$

$K = 6.34$



SHEET 7 RUN 3

Q

J H WEIL & CO PHILA 10 X 10 TO 1 INCH

SHEET 7 RUN 3 16 × 36 × .040 24ST6 T3 ALUM WITH 4.5" HOLE

3/25/57
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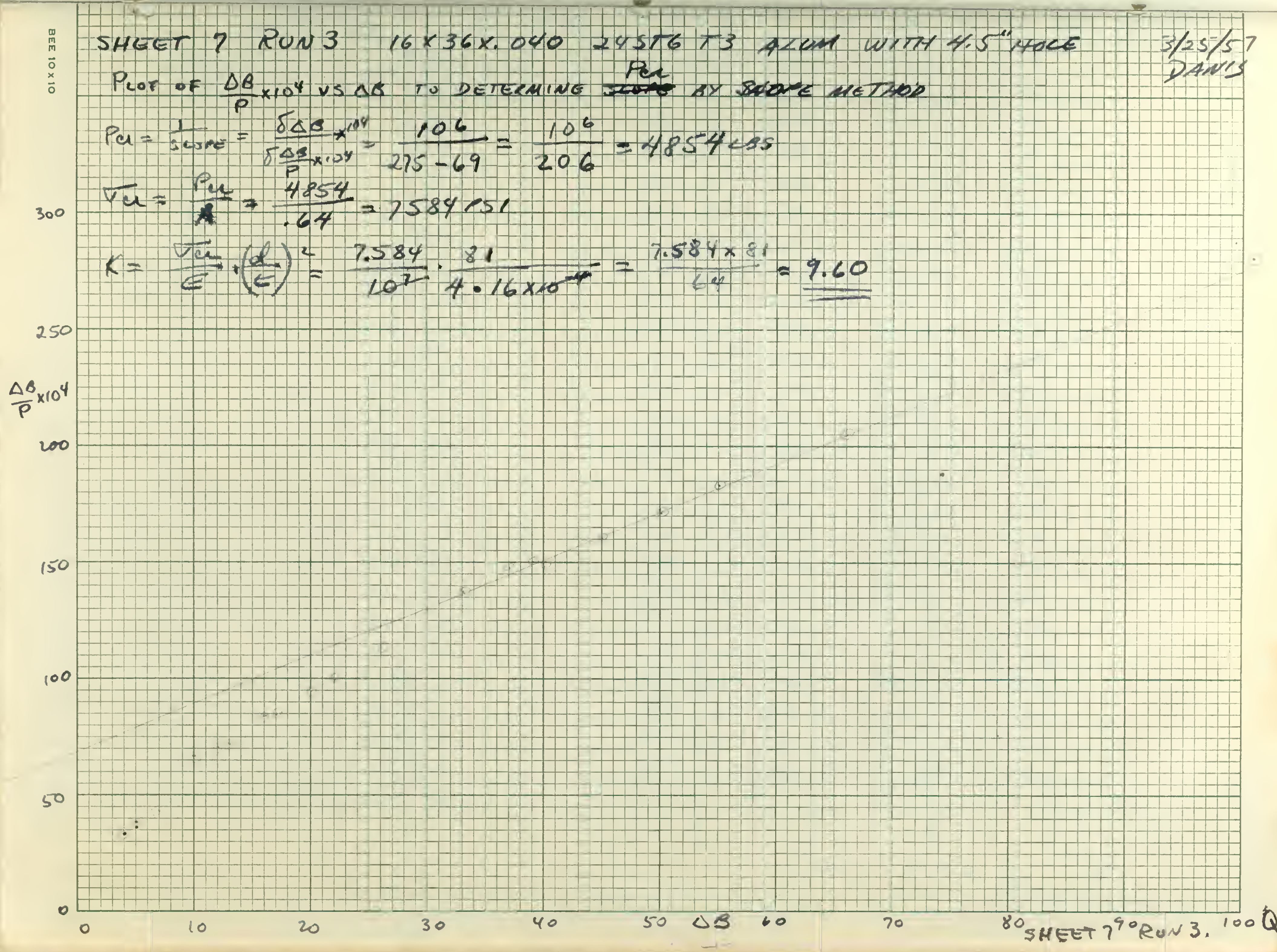
PLOT OF $\frac{\Delta B}{P} \times 10^4$ VS ΔB TO DETERMINE ~~SLOPE~~ P_{cr} BY ~~SLOPE~~ METHOD

$$P_{cr} = \frac{1}{\text{SLOPE}} = \frac{\delta \Delta B \times 10^4}{\delta \frac{\Delta B}{P} \times 10^4} = \frac{106}{275 - 69} = \frac{10^6}{206} = 4854 \text{ LBS}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{4854}{.64} = 7584 \text{ PSI}$$

$$K = \frac{\sigma_{cr}}{E} \cdot \left(\frac{d}{t}\right)^2 = \frac{7.584}{10^{4}} \cdot \frac{81}{4 \cdot 16 \times 10^{\cancel{-4}}} = \frac{7.584 \times 81}{64} = \underline{\underline{9.60}}$$



SHEET 7 RUN 3.

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P} \times 10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
0		2962	0			200		
100	100	2962	0			240		
200	50	2975	-13			280		
300	33.3	2970	- 8			326		
400	25	2980	-18			365		
500	20	2965	- 3			400		
600	16.7	2962	0			439		
700	14.3	2960	+ 2	28.57	5000	478		
800	12.5	2960	+ 2	25.00	5000	512		
900	11.1	2952	+10	111.10	1000	550		
1000	10.0	2950	12	120.0	833	589		
1100	9.09	2950	12	109.1	833	628		
1200	8.33	2942	20	166.7	500	663		
1300	7.69	2932	30	230.7	333	702		
1400	7.14	2932	30	214.3	333	745		
1500	6.67	2920	42	280.0	238	780		
1600	6.24	2919	43	268.8	233	819		
1700	5.88	2908	54	317.6	185	854		
1800	5.56	2900	62	344.4	161	892		
1900	5.26	2880	82	431.6	122	930		
2000	5.00	2872	90	450.0	111	972		
2100	4.76	2855	107	509.5	93.5	1012		
2200	4.54	2830	132	600.0	75.8	1052		
2300	4.35	2802	160	695.7	62.5	1090		
2400	4.16	2769	193	804.2	51.8	1132		
2500	4.00	2725	237	948.0	42.2	1172		

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
2600	3.84	2662	300	1154.	33.3	214		
2700	3.70	2600	362	1341.	27.6	256		
2800	3.57	2528	434	155.0	23.0	298		
2900	3.45	2449	513	1769	19.5	338		
3000	3.33	2365	597	1990	16.8	379		
3100	3.23	2281	671	2165	14.9	423		
3200	3.13	2185	777	2428	12.9	465		
3300	3.03	2096	866	2624	11.5	508		
3400	2.94	2000	962	2829	10.4	550		
3500	2.86	1905	1057	3020	9.43	598		
3600	2.78	1826	1136	3155	8.77	634		
3700	2.70	1734	1228	3318	8.13	682		
3800	2.63	1648	1314	3458	7.63	728		
3900	2.56	1568	1394	3574	7.19	770		
4000	2.50	1490	1472	3680	6.80	812		
4100	2.44	1409	1553	3788	6.45	856		
4200	2.38	1325	1637	3898	6.10	904		
4300	2.32	1255	1707	3970	5.85	945		
4400	2.27	1180	1782	4050	5.62	990		
4500	2.22	1100	1862	4138	5.38	1038		
4600	2.17	1033	1929	4193	5.18	1080		
4700	2.13	965	1997	4248	5.00	1120		
4800	2.08	892	2070	4312	4.83	1172		
4900	2.04	812	2150	4388	4.65	1225		
5000	2.00	752	2210	4420	4.52	1272		

RP-450

SHEET 8 RUN 4 ✓

$$K = \frac{\sigma a}{E} \cdot \left(\frac{d}{t}\right)^2$$

$$\frac{1000}{16}$$

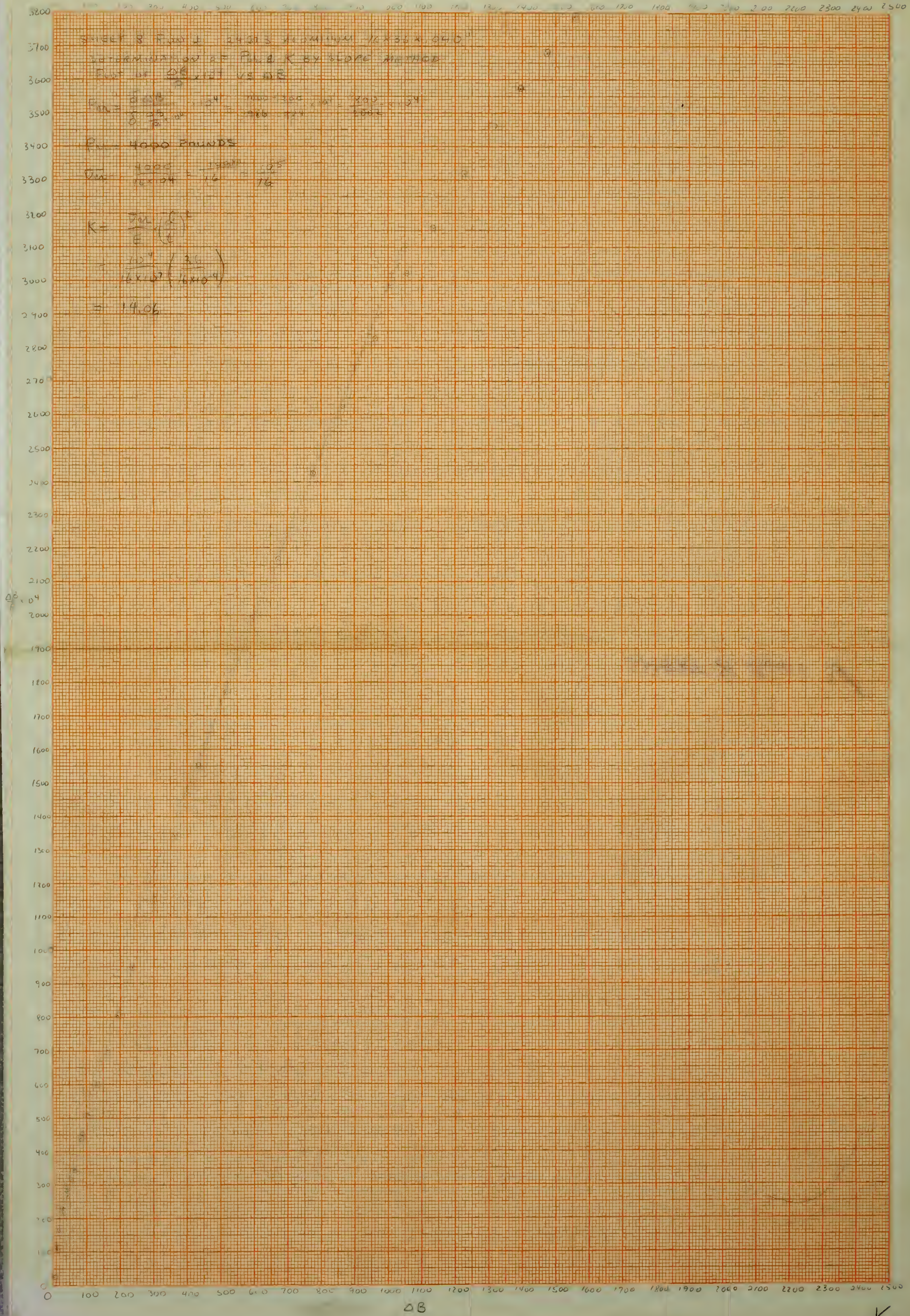
$$= \frac{10^5}{16 \times 10 \times \cancel{10}} \left(\frac{6 \cdot 6}{16 \times \cancel{64}}\right)$$

$$\frac{[illegible]}{16}$$

$$\left(\frac{9}{64}\right) 10^2$$

```
     14.06
64 ) 900
     64
     260
     256
      400
```

```
     .375
16 ) 6.0
     48
     120
     112
      80
```



SHEET 3 Rod 1 24ST3 ALUMINUM 1/2 x 36 x .040"

DETERMINATION OF P_{cr} & K BY SLOPE METHOD

PLOT OF $\frac{\Delta B}{B}\times 10^4$ VS ΔB

$P_{cr} = \frac{\Delta B}{\delta \frac{\Delta B}{B}\times10^4}\times10^4 = \frac{[illegible] - 300}{986 - 124}\times10^4 = \frac{[illegible]}{[illegible]}\times10^4$

P_{cr} = 4000 POUNDS

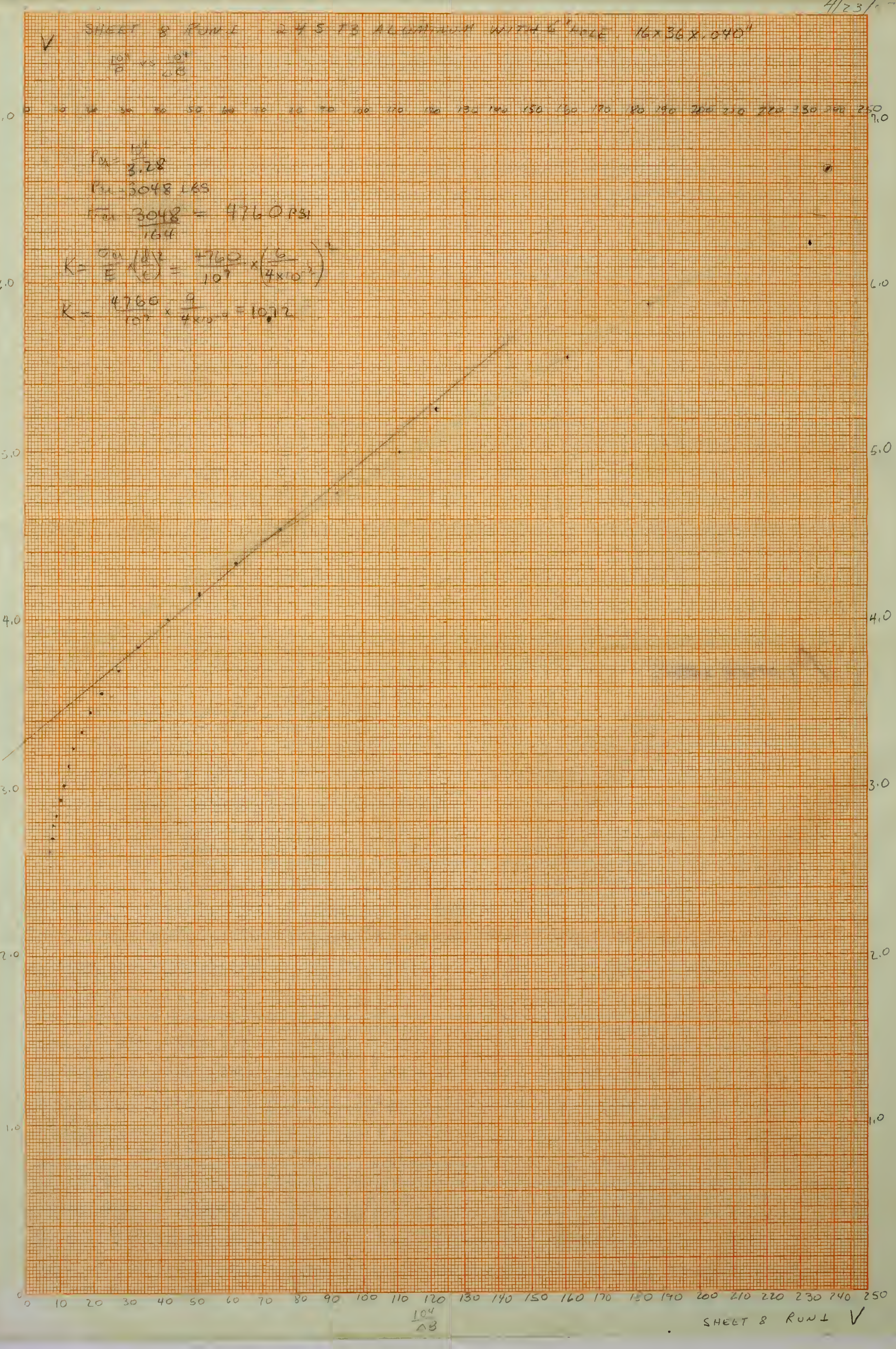
$\sigma_{cr} = \frac{4000}{16\times.04} = \frac{[illegible]}{16} = \frac{.25}{16}$

$K = \frac{\sigma_{cr}}{E}\left(\frac{b}{t}\right)^2$

$= \frac{10^4}{1.6\times10^7}\left(\frac{36}{16\times10^{-4}}\right)$

= 14.06

4/23/



SHEET 8 RUN 1 24S T3 ALUMINUM WITH 6" HOLE 16 x 36 x .040"

$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta B}$

$P_{cr} = \frac{10^4}{3.28}$

$P_{cr} = 3048$ LBS

$\sigma_{cr} = \frac{3048}{.64} = 4760$ PSI

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{b}{t}\right)^2 = \frac{4760}{10^7} \times \left(\frac{6}{4 \times 10^{-2}}\right)^2$

$K = \frac{4760}{10^7} \times \frac{9}{4 \times 10^{-4}} = 10.72$

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P} \times 10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
0		2930	0			1178.		
100		2950	-20			1218		
200		2942	-18			1261		
300		2943	-13			1305		
400		2938	- 8			1344		
500		2935	- 5			1378		
600		2930	0	—		1422		
700		2933	- 3			1460		
800	12.5	2922	+ 8	100	1250	1498		
900	11.1	2920	10	111.1	1000	1532		
1000	10.0	2912	18	180.0	556	1572		
1100	9.09	2909	21	190.9	476	[illegible]		
1200	8.33	2905	25	208.3	400	1646		
1300	7.69	2900	30	230.7	333	1683		
1400	7.14	2896	34	242.9	294	1723		
1500	6.67	2889	41	273.3	244	1762		
1600	6.24	2885	45	281.2	222	1800		
1700	5.88	2872	58	341.1	173	1835		
1800	5.56	2870	60	333.3	167	1874		
1900	5.26	2855	75	394.7	133	1912		
2000	5.00	2842	88	440.0	114	1950		
2100	4.76	2814	116	552.3	86.2	1987		
2200	4.54	2800	130	590.9	76.9	—		
2300	4.35	2762	168	730.4	57.5	2067		
2400	4.16	2735	195	812.5	51.3	[illegible]		
2500	4.00	2682	248	992.0	40.3	2150		

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
2600	3.84	2626	304	1169	32.9	2190		
2700	3.70	2561	369	1367	27.1	2231		
2800	3.57	2475	455	1625	21.9	2274		
2900	3.45	2405	525	1810	19.0	2315		
3000	3.33	2310	620	2067	16.1	2358		
3100	3.23	2212	718	2316	13.9	2400		
3200	3.13	2118	812	2537	12.3	2443		
3300	3.03	2025	905	2742	11.0	2486		
3400	2.94	1960	970	2853	10.3	2530		
3500	2.86	1862	1068	3051		2572		
3600	2.78	1778	1152	3200		2616		
3700	2.70	1691	1239	[illegible]		2656		
3800	2.63	1600	1330	3500		2702		
3900	2.56	1510	1420	3641		2746		
400	2.50	1440	1490	3725		2785		
4100	2.44	1352	1578	3849		2832		
4200	2.38	1270	1660	3952		2879		
4300	2.32	1190	1740	4047		2925		
4400	2.27	1128	1802	4095		2965		
[illegible]	2.22	1050	1880	4177		[illegible]		
[illegible]	2.17	[illegible]	1956	4252		[illegible]		
4700	2.13	871	2039	4338		[illegible]		
4800	2.08	822	2108	4392		3149		
4900	2.04	750	2180	4449		3194		
5000	2.00	668	2262	4524		3245		

RR

SI/CZT 8 RUN 2

RP-450

TIME USED PER SHEET

2.5 HRS RUNNING EXAMPLES &
CORRECTING ERRORS

2.0 HRS FOR ERRORS

2.0 HRS COMPUTATIONS

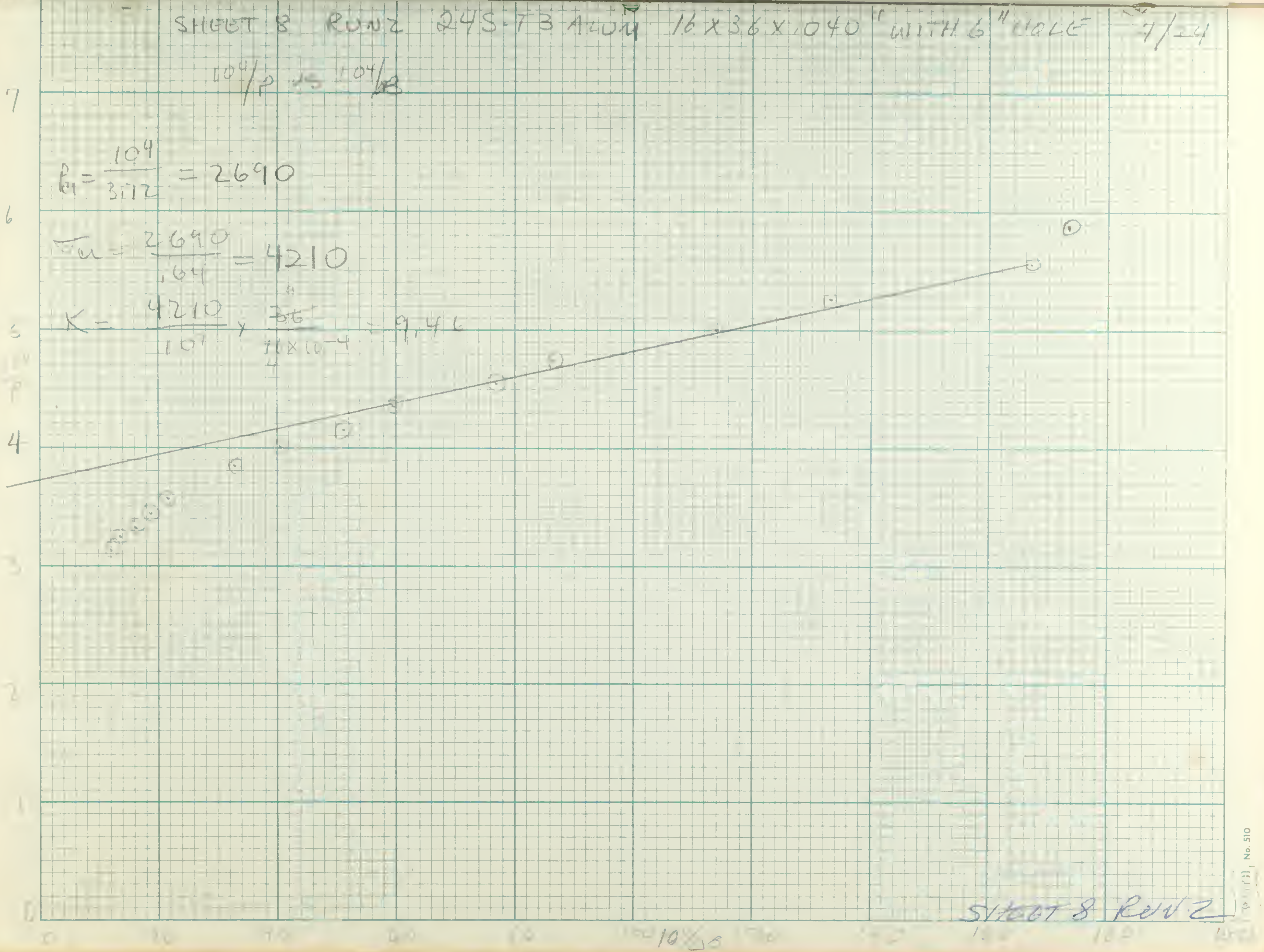
.5 HRS PLOTTING DATA

.3 HRS COMPUTER I/O

7.3 HRS PER SHEET.

SHEET 8 RUN 2 24S-T3 ALUM 16 × 36 × .040" WITH 6" HOLE 7/24

$10^4/P$ vs $10^4/B$



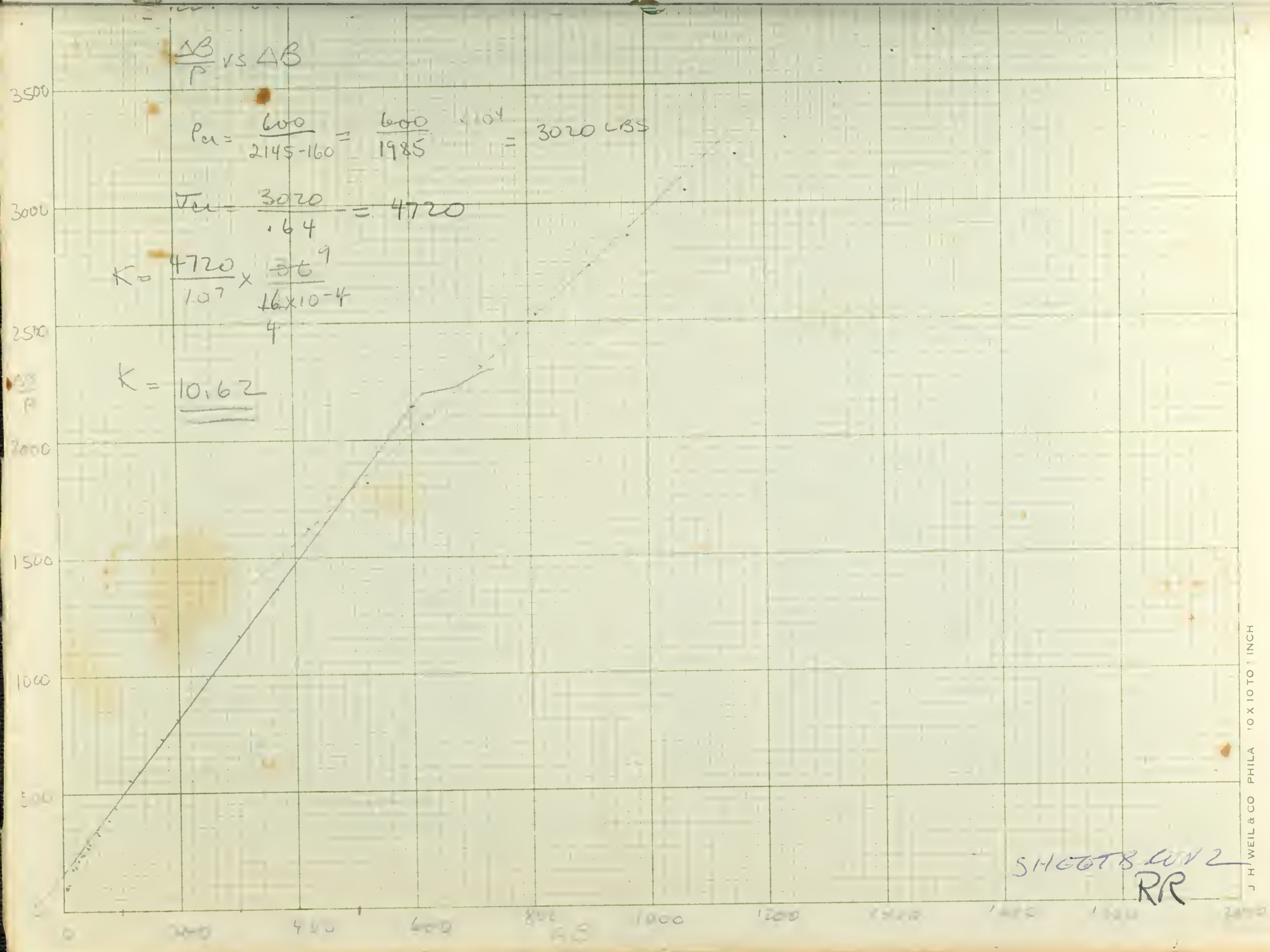
$P_{cr} = \frac{10^4}{3.72} = 2690$

$\sigma_u = \frac{2690}{.64} = 4210$

$K = \frac{4210}{10^4} \times \frac{36^4}{\underset{4}{11 \times 10^{-4}}} = 9.46$

SHEET 8 RUN 2

No. 510



$\frac{\Delta B}{P}$ vs ΔB

$P_{cr} = \frac{600}{2145-160} = \frac{600}{1985} \times 10^4 = 3020$ LBS

$\sigma_{cr} = \frac{3020}{.64} = 4720$

$K = \frac{4720}{10^7} \times \frac{\cancel{36}^{9}}{\cancel{16}_{4}\times10^{-4}}$

$K = \underline{\underline{10.62}}$

SHEET 8 CUV 2
RR

J H WEIL & CO PHILA 10 X 10 TO 1 INCH

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS PSI
0		2975	0			1125		
100		2982	-7			1165		
200		2982	-7			1198		
300		2982	-7			1240		
400		2982	-7					
500		2981	-6			1320		
600		2978	-3			1458		
700	14.3	2972	+3	42.85	3333	1390		
800	12.5	2972	+3	37.50	3333	1432		
900	11.1	2958	17	188.0	588	1470		
1000	10.0	2968	7	70.0	1430	1508		
1100	9.09	2952	23	209.0	435	1545		
1200	8.33	2950	25	208.3	400	1582		
1300	7.69	2952	23	[illegible]	435	1620		
1400	7.14	2935	40	[illegible]	250	1660		
1500	6.67	2932	43	286.7	232	1700		
1600	6.24	2925	50	312.5	200	1740		
1700	5.88	2910	65	382.3	154	1775		
1800	5.56	2908	67	372.2	149	1812		
1900	5.26	2884	91	[illegible]	110	1855		
2000	5.00	2872	103	[illegible]	97.1	1894		
2100	4.76	2855	120	571.4	83.3	1930		
2200	4.54	2829	146	663.6	68.5	1970		
2300	4.35	2800	175	760.8	57.1	2005		
2400	4.16	2775	200	833.3	50.0	–		
2500	4.00	2722	253	1012	39.5	2093		

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS PSI
2600	3.84	2665	310	1192	32.3	2132		
2700	3.70	2600	375	1389	26.7	2172		
2800	3.57	2531	444	1586	22.5	2215		
2900	3.45	2458	517	1783	19.3	2256		
3000	3.33	2370	605	2016	16.5	2300		
3100		2261	714	2303	14.0	2346		
3200	3.13	2175	800	2500	12.5	2385		
3300		2100	875	2652	11.4	2428		
3400	2.94	1972	1003	2950		2468		
3500		1876	1099	3140	10.9	2516		
3600	2.78	1792	1183	3286	84.7	2557		
3700		1702	1273	3441	[illegible]	2601		
3800	2.63	1615	1360	3578	[illegible]	2646		
3900		1532	1443	3700	[illegible]	2690		
4000	2.50	1455	1520	[illegible]	[illegible]	2732		
4100		1368	1607	3920	[illegible]	2778		
4200		1288	1687	4017	24.8	2826		
4300		1202	1773	[illegible]	[illegible]	2871		
4400		1128	1847	4198	[illegible]	2913		
4500		1058	1917	[illegible]	[illegible]	2960		
4600		979	1996	[illegible]	[illegible]	3005		
4700		906	2069	[illegible]	22.1	3050		
4800		832	2143	4465	[illegible]	3198		
4900		762	2213	[illegible]	19.1	3143		
5000	2.100	670	2305	4610	21.7	3200		

SHEET 8 RUN 3 Y

$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta B}$.

4/25

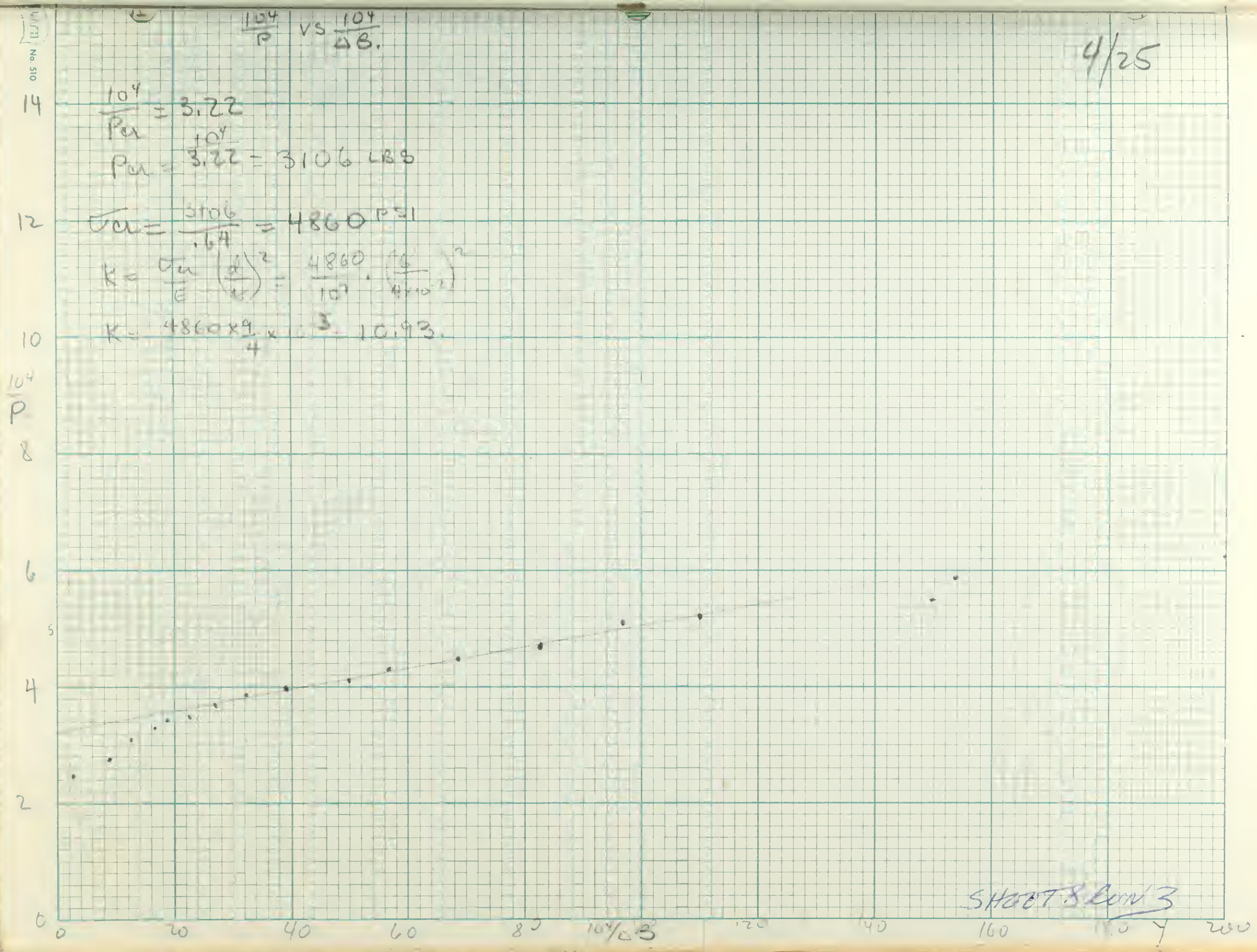
$\frac{10^4}{P_{cr}} = 3.22$

$P_{cr} = \frac{10^4}{3.22} = 3106$ LBS

$\sigma_{cr} = \frac{3106}{.64} = 4860$ PSI

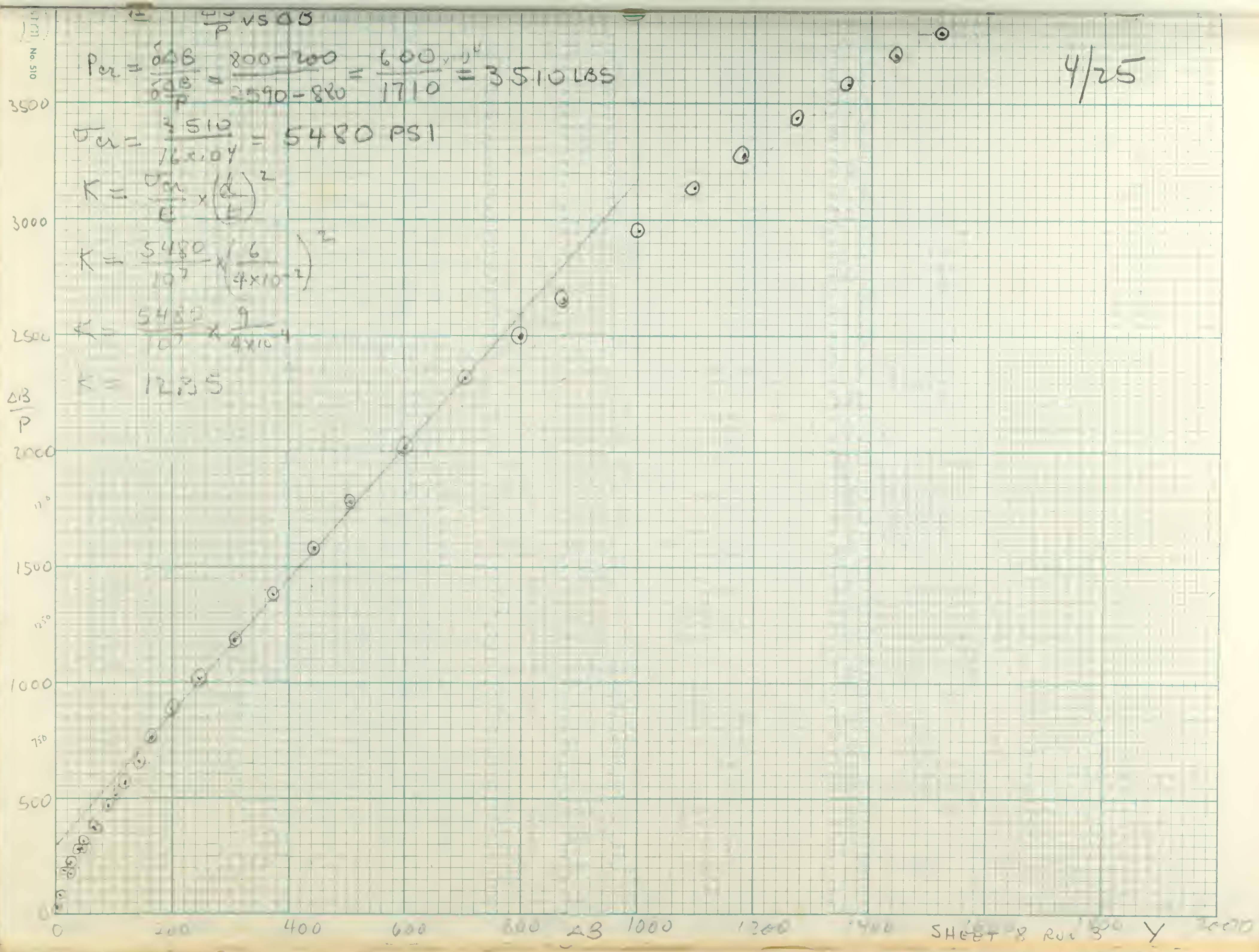
$K = \frac{\sigma_{cr}}{E}\left(\frac{\ell}{t}\right)^2 = \frac{4860}{10^7} \cdot \left(\frac{[illegible]}{4 \times 10^{[illegible]}}\right)^2$

$K = \frac{4860 \times 9}{4} \times$ [illegible] 3 10.93.



SHEET 8 Curv 3

No. 510



$\frac{\Delta B}{P}$ vs ΔB

$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P}} = \frac{800-200}{2590-880} = \frac{600}{1710} \times 10^{4} = 3510$ LBS

$\sigma_{cr} = \frac{3510}{16 \times .04} = 5480$ PSI

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{d}{t}\right)^2$

$K = \frac{5480}{10^7} \times \left(\frac{6}{4\times10^{-2}}\right)^2$

$K = \frac{5480}{10^7} \times \frac{9}{4\times10^{-4}}$

$K = 12.35$

4/25

No. 510

RUN I

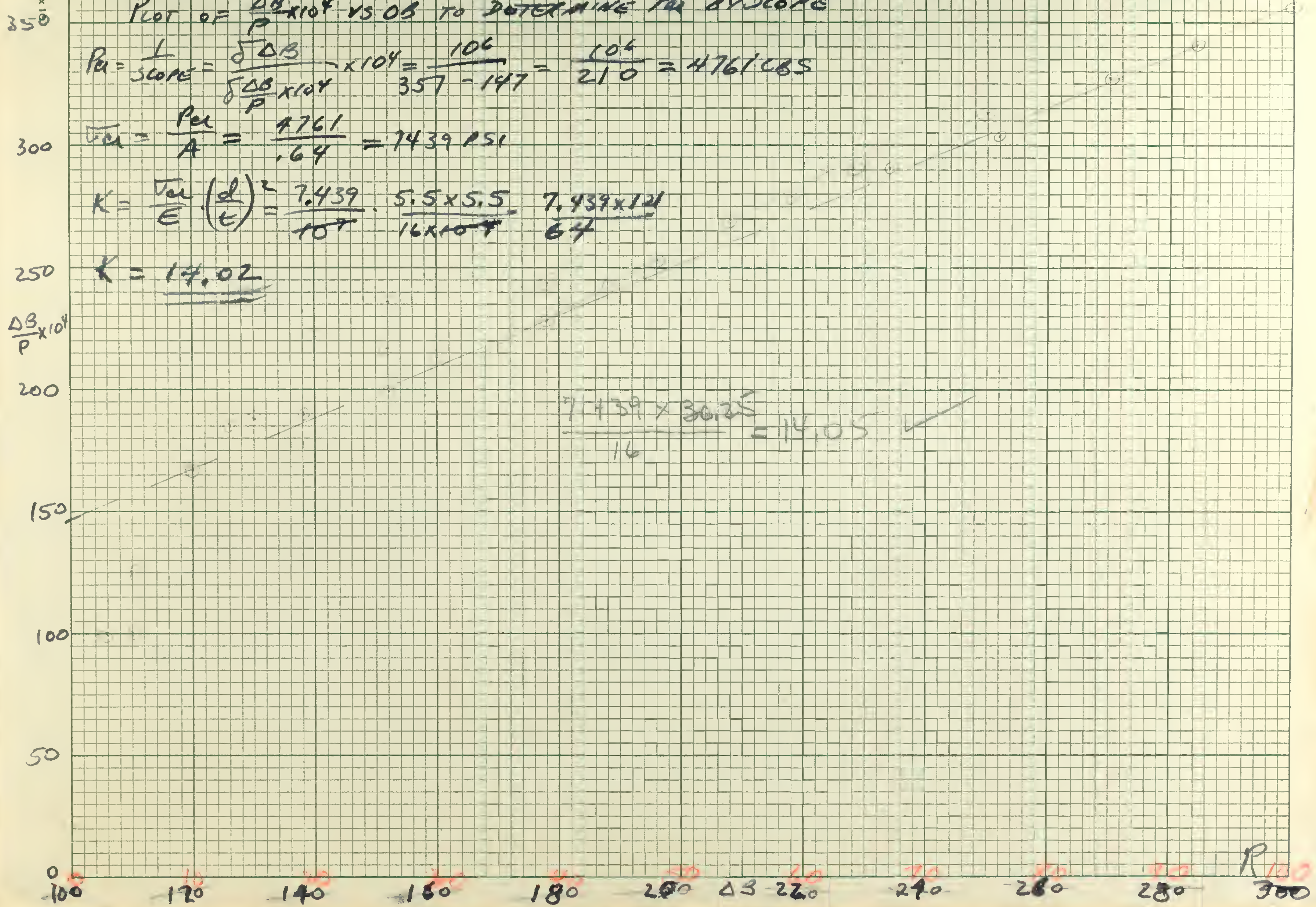
LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STR
0		1348	0					
100	100	1348	0					
200	50	1339	9		450			
300	33.3	1345	3	3333	100			
400	25	1343	5	2000	125			
500	20	1343	5	2000	100			
600	16.7	1338	10	1000	167			
700	14.3	1335	13	769	186			
800	12.5	1333	15	667	188			
900	11.1	1328	20	500	222			
1000	10.0	1329	19	526	190			
1100	9.09	1322	26	384	236			
1200	8.33	1322	26	384	217			
1300	7.69	1322	26	384	200			
1400	7.14	1318	30	333	214			
1500	6.67	1312	36	277	240			
1600	6.24	1309	39	256	244			
[illegible]	5.88	1309	39	256	229			
1800	5.56	1304	44	227	244			
1900	5.26	1300	48	208	253			
2000	5.00	1294	54	185	270			
2100	4.76	1289	59	169	281			
2200	4.54	1284	64	156	291			
2300	4.35	1281	67	149	291			
2400	4.16	1273	75	133	313			

LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	T	
2500	4.00	1272	76	132	304			
2600	3.84	1263	85	118	327			
2700	3.70	1256	92	109	341			
2800	3.57	1248	100	100	357			
2900	3.45	1235	113	88.5	390			
3000	3.33	1219	129	77.5	430			
3200	3.13	1186	162	61.7	506			
3400	2.94	1138	210	47.6	618			
3600	2.78	1064	284	35.2	789			
3800	2.63	945	403	24.8	1060			
4000	2.50	788	660	15.2	1650			

RP-450

SHEET 9 RUN I

R



SHEET 9 RUN I 16 X 36 X .040 24ST6-T3 ALUM WITH 5.5" HOLE.

3/26/57
DAVIS

PLOT OF $\frac{\Delta B}{P}\times 10^4$ VS ΔB TO DETERMINE P_{cr} BY SLOPE

$P_{cr} = \frac{1}{\text{SLOPE}} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P}\times 10^4}\times 10^4 = \frac{10^6}{357-147} = \frac{10^6}{210} = 4761$ LBS

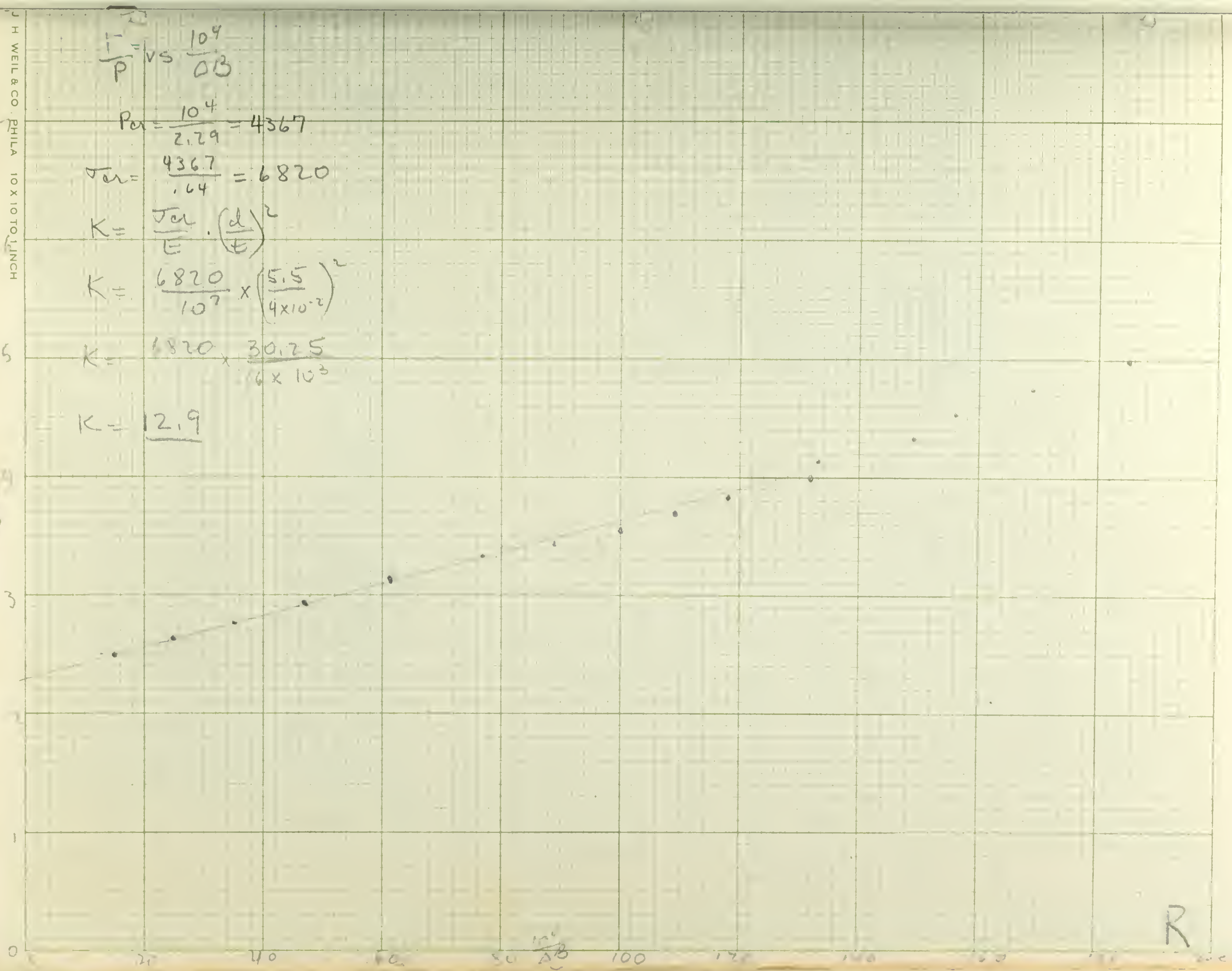
$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{4761}{.64} = 7439$ PSI

$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \frac{7.439}{\cancel{10^7}}\cdot\frac{5.5\times 5.5}{16\times\cancel{10^{-4}}} = \frac{7.439\times 121}{64}$

$K = \underline{\underline{14.02}}$

$\frac{7.439\times 30.25}{16} = 14.05$ ✓

J H WEIL & CO. PHILA 10 X 10 TO 1 INCH



$\frac{1}{P}$ vs $\frac{10^4}{\Delta B}$

$P_{cr} = \frac{10^4}{2.29} = 4367$

$\sigma_{cr} = \frac{4367}{.64} = 6820$

$K = \frac{\sigma_{cr}}{E} \cdot \left(\frac{d}{t}\right)^2$

$K = \frac{6820}{10^7} \times \left(\frac{5.5}{4 \times 10^{-2}}\right)^2$

$K = 6820 \times \frac{30.25}{16 \times 10^3}$

$K = \underline{12.9}$

7

LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS	LOAD P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS
0		1360	0	—					2500	4.00	1270	90	111	360			
100	100	1345	15		1500				2600	3.84	1261	99	101	381			
200	50	1341	19		950				2700	3.70	1252	108	92.6	400			
300	33.3	1341	19		633				2800	3.57	1242	118	84.7	421			
400	25	1343	17		425				2900	3.45	1238	122	81.9	421			
500	20	1340	20		400				3000	3.33	1220	140	71.4	467			
600	16.7	1338	22		367				3200	3.13	1194	166	60.2	518			
700	14.3	1334	26		371				3400	2.94	1140	220	45.5	647			
800	12.5	1335	25		313				3600	2.78	1062	298	33.6	828			
900	11.1	1331	29		322				3800	2.63	944	416	24.0	1095			
1000	10.0	1330	30		300				4000	2.50	782	578	17.3	1445			
1100	9.09	1328	32		291												
1200	8.33	1325	35		291												
1300	7.69	1322	38		292												
1400	7.14	1319	41	244	293												
1500	6.67	1318	42	238	280												
1600	6.24	1310	50	200	313												
1700	5.88	1309	51	196	300												
1800	5.56	1301	59	169	328												
1900	5.26	1300	60	167	316												
2000	5.00	1299	61	164	305												
2100	4.76	1292	68	147	324												
2200	4.54	1289	71	141	323												
2300	4.35	1282	78	128	339												
2400	4.16	1278	82	122	342												

RP-450

SHEET 9 RUN 2

S

SHEET 9 RUN 2 16 x 36 x .040" [illegible] ALUM WITH 5.5" HOLE 3/26/57
DAVIS

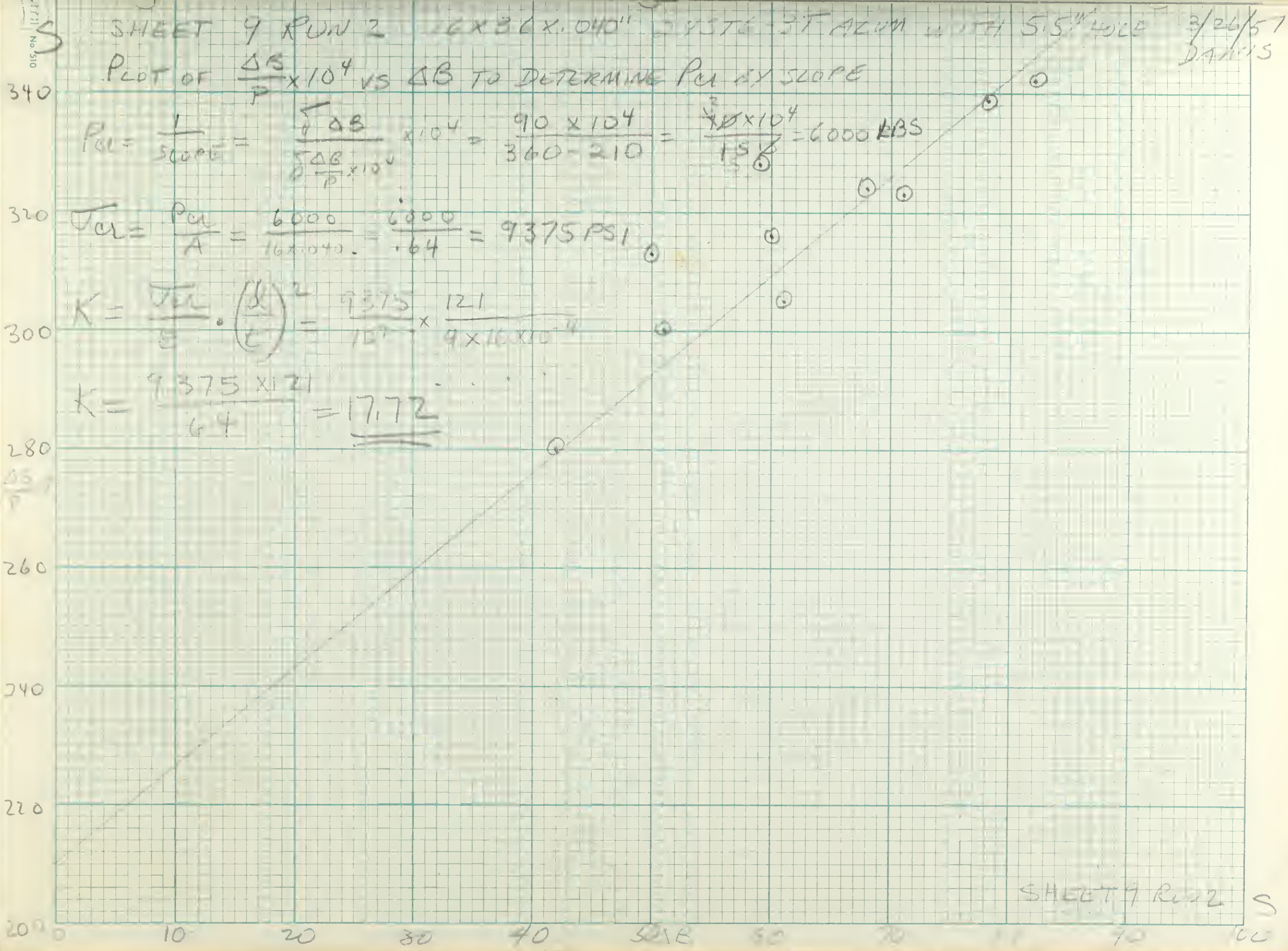
PLOT OF $\frac{\Delta B}{P} \times 10^4$ VS ΔB TO DETERMINE P_{cr} BY SLOPE

$P_{cr} = \frac{1}{SLOPE} = \frac{\int \Delta B}{\int \frac{\Delta B}{P} \times 10^4} \times 10^4 = \frac{90 \times 10^4}{360 - 210} = \frac{\overset{2}{\cancel{90}} \times 10^4}{15\cancel{0}} = 6000$ LBS

$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{6000}{16 \times .040} = \frac{6000}{.64} = 9375$ PSI

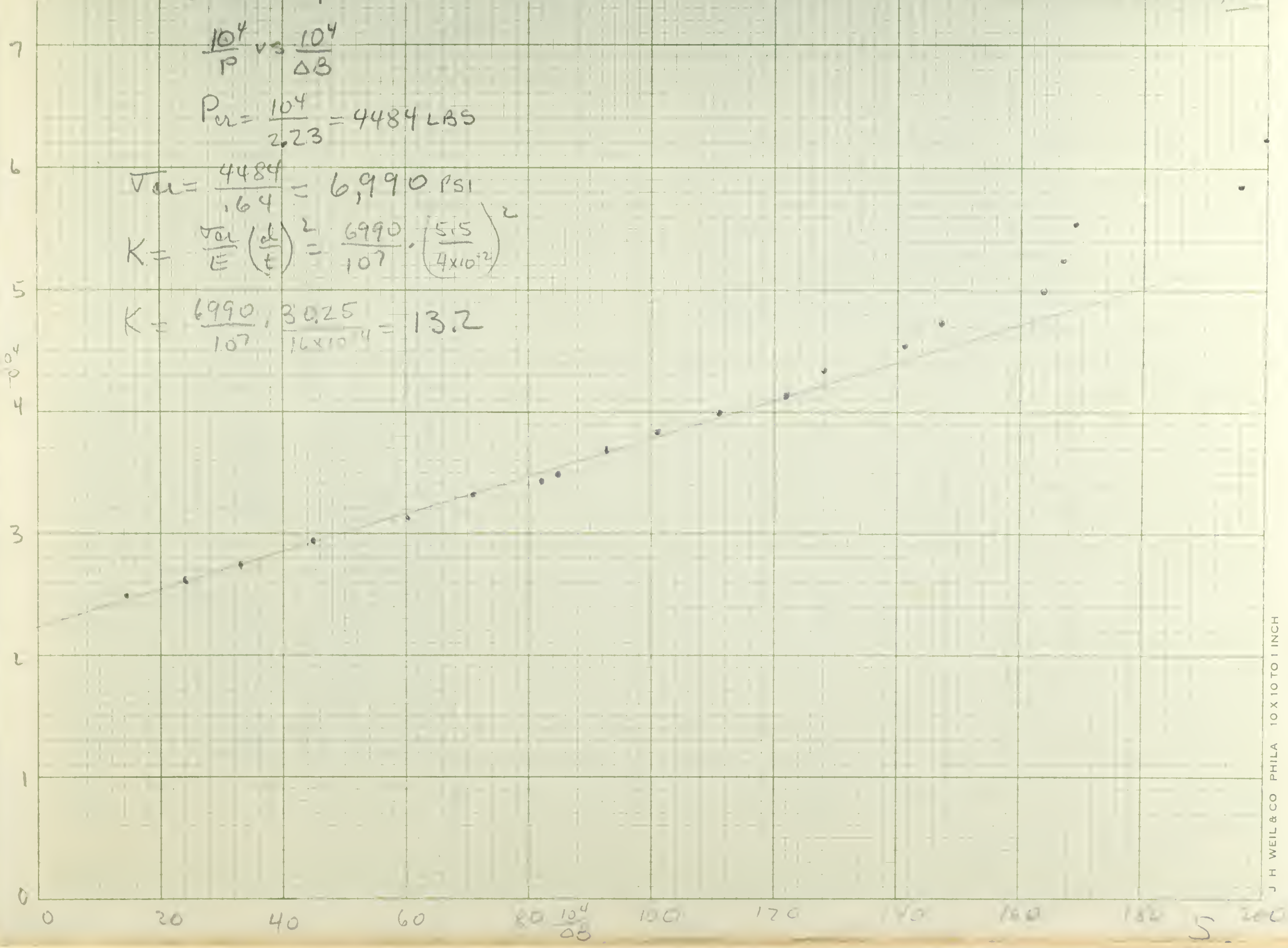
$K = \frac{\sigma_{cr}}{E} \cdot \left(\frac{b}{t}\right)^2 = \frac{9375}{10^7} \times \frac{121}{4 \times 16 \times 10^{-4}}$

$K = \frac{9375 \times 121}{64} = \underline{\underline{17.72}}$



SHEET 9 RUN 2

SHEET 9 RUN 2 16 x 36 x .040" WITH 5.5" HOLE. 3/26



$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta B}$

$P_{cr} = \frac{10^4}{2.23} = 4484$ LBS

$\sigma_{cr} = \frac{4484}{.64} = 6,990$ PSI

$K = \frac{\sigma_{cr}}{E}\left(\frac{d}{t}\right)^2 = \frac{6990}{10^7}\cdot\left(\frac{5.5}{4\times10^{-2}}\right)^2$

$K = \frac{6990}{10^7}\cdot\frac{30.25}{16\times10^{-4}} = 13.2$

5

J H WEIL & CO PHILA 10 X 10 TO 1 INCH

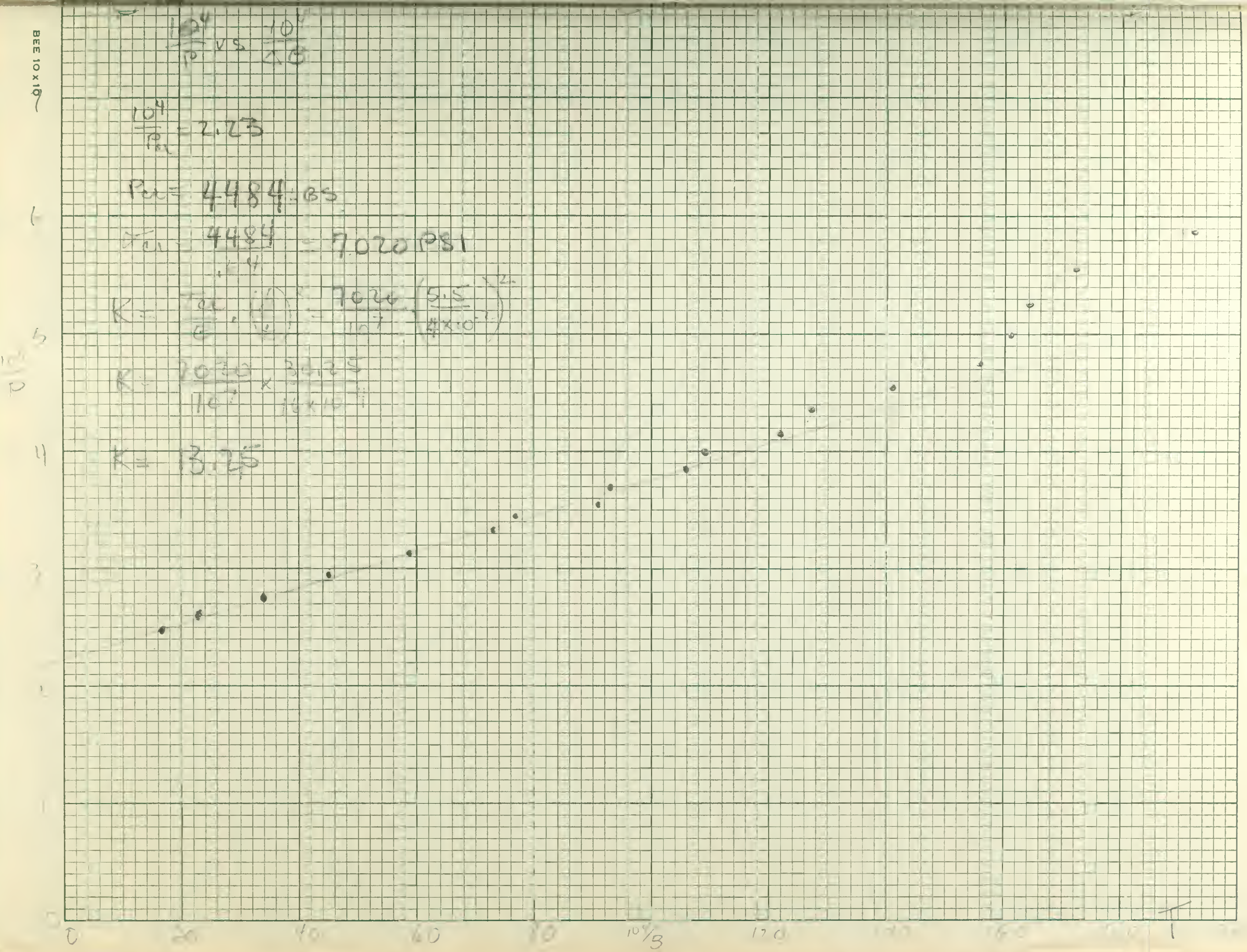
P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS
0		1362	—					
100	100	1350	12		1200			
200	50	1352	10		500			
300	33.3	1342	20		667			
400	25	1350	12		300			
500	20	1339	23		460			
600	16.7	1336	26		433			
700	14.3	1338	24		343			
800	12.5	1337	25		313			
900	11.1	1332	30		333			
1000	10.0	1330	32		320			
1100	9.09	1328	34		309			
1200	8.33	1322	40		333			
1300	7.69	1320	42	238	323			
1400	7.14	1322	40	250	286			
1500	6.67	1318	44	227	293			
1600	6.24	1315	47	213	294			
1700	5.88	1310	52	192	306			
1800	5.56	1304	58	172	322			
1900	5.26	1301	61	164	321			
2000	5.00	1300	62	161	310			
2100	4.76	1298	64	156	305			
2200	4.54	1291	71	141	323			
2300	4.35	1283	79	127	343			
2400	4.16	1280	82	122	342			

P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P} \times 10^4$	T	ΔT	STRESS
2500	4.00	1270	92	109	368			
2600	3.84	1268	94	106	362			
2700	3.70	1255	107	93.5	396			
2800	3.57	1250	112	89.3	400			
2900	3.45	1232	130	76.9	448			
3000	3.33	1225	137	73.0	457			
3200	3.13	1194	168	59.5	525			
3400	2.94	1140	222	45.0	653			
3600	2.78	1068	294	34.0	817			
3800	2.63	942	420	23.8	1105			
4000	2.50	782	580	17.2	1450			

RP-450

SHEET 9 RUN 3

T



$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta\delta}$

$\frac{10^4}{P_{cr}} = 2.23$

$P_{cr} = 4484$ lbs

$\sigma_{cr} = \frac{4484}{.64} = 7020$ PSI

$K = \frac{\sigma_{cr}}{E}\cdot\left(\frac{b}{t}\right)^2 = \frac{7020}{10^7}\left(\frac{5.5}{4\times10^{-2}}\right)^2$

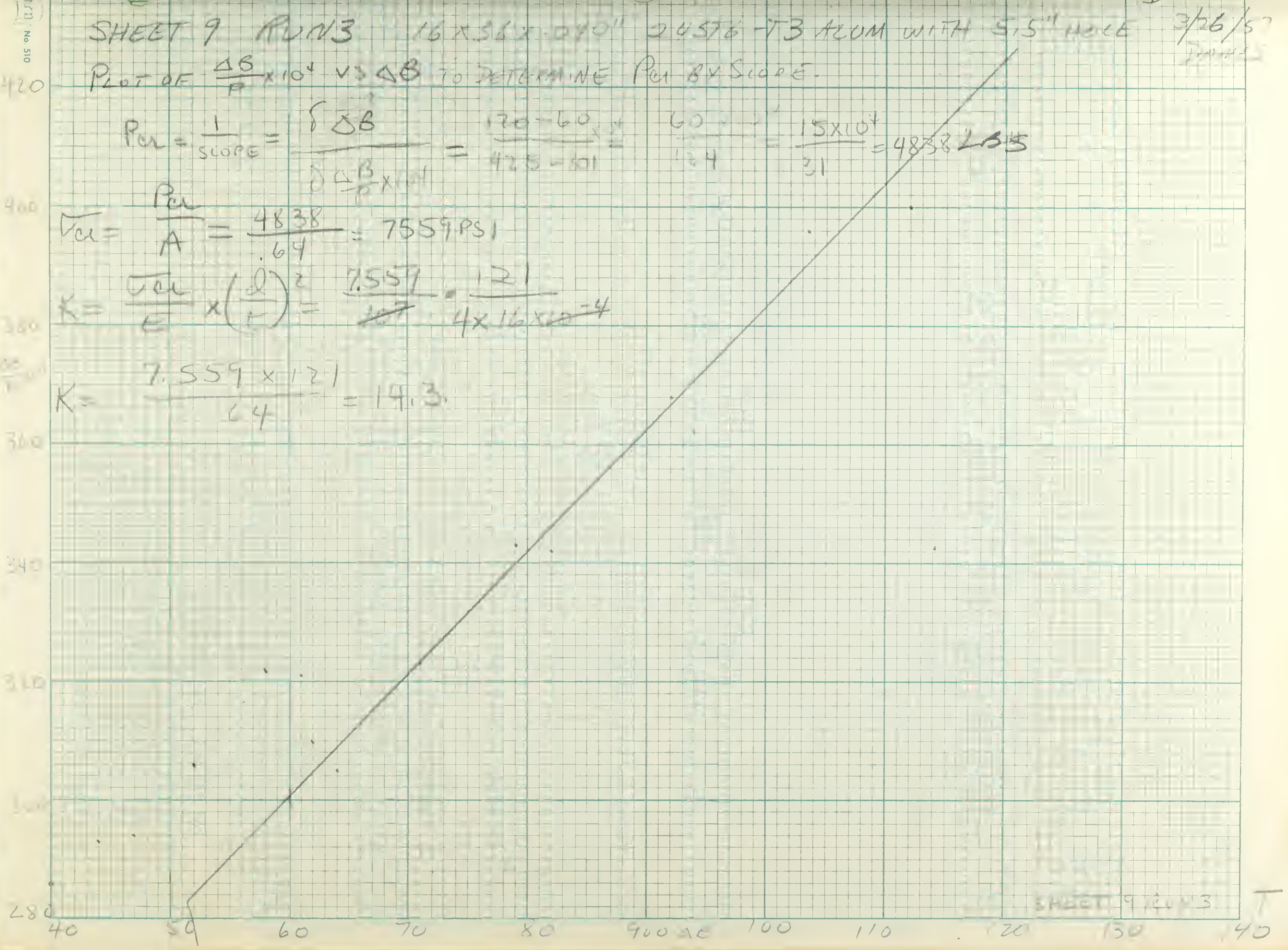
$K = \frac{7020}{10^7}\times\frac{30.25}{16\times10^{-4}}$

$K = 13.25$

BEE 10 x 10

SHEET 9 RUN 3 16 x 56 x .040" 24ST6-T3 ALUM WITH 5.5" HOLE 3/26/57

PLOT OF $\frac{\Delta B}{P} \times 10^4$ VS ΔB TO DETERMINE P_{cr} BY SLOPE.



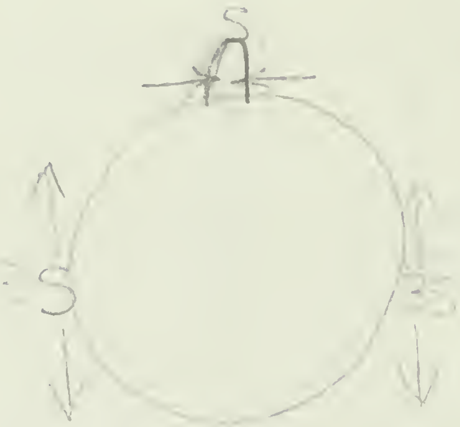
$$P_{cr} = \frac{1}{SLOPE} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} = \frac{120-60}{425-301} \times 10^4 = \frac{60}{124} = \frac{15 \times 10^4}{31} = 4838 \text{ LBS}$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{4838}{.64} = 7559 \text{ PSI}$$

$$K = \frac{\sigma_{cr}}{E} \times \left(\frac{l}{t}\right)^2 = \frac{7559}{\cancel{10^7}} \cdot \frac{121}{4 \times 16 \times \cancel{10^{-4}}}$$

$$K = \frac{7.559 \times 121}{64} = 14.3$$

S



P	$^{10}/P$	B	ΔB	$\frac{\Delta B}{P}$	$\frac{10^4}{\Delta B}$
0					
100					
200					
300					
400					
[illegible]					
600					
700					
800					
900					
[illegible]					
[illegible]					
[illegible]					
0		630	0		—
100	100	638	-8		
200	50	638	-8		
300	33.3	631	-1		
400	25	630	0		—
600	16.7	628	2	33.3	5000
800	12.5	625	5	62.5	2000
1000	10.0	620	10	100	1000
1200	8.33	612	18	150	556
1400	7.14	608	22	157	455
1600	6.24	602	28	175	357
1800	5.56	602	28	156	357
2000	5	598	32	160	313

P	$^{10^4}/P$	B	ΔB	$\frac{\Delta B}{P}$	$^{10^4}/\Delta B$
2200	4.54	578	52	236	192
2400	4.16	570	60	250	167
2600	3.84	558	72	277	139
2800	3.57	560	70	250	143
3000	3.33	543	87	290	115
3200	3.13	541	89	278.1	112
3400	2.94	532	98	288.2	102
3600	2.78	525	105	291	15.2
3800	2.63	523	107	281	93.4
4000	2.50	512	118	295	84.7
4200	2.38	502	128	304	78.1
4400	2.27	494	136	309	73.5
4600	2.17	488	142	308	70.4
4800	2.08	475	155	322	64.5
5000	2.00	474	156	312	64.1
5200	1.92	468	162	311	61.7
5400	1.85	462	168	311	59.5
5600	1.78	449	181	323	55.2
5800	1.72	439	191	329	52.4
6000	1.67	436	194	323	51.5
6200	1.61	428	202	325	49.5
6400	1.56	421	209	326	47.8
6600	1.51	409	221	334	45.2
6800	1.47	392	238	350	42.0
6400	1.45	391	239	346	41.8
7000	1.43	390	240	342	41.6

AA.

RP-450

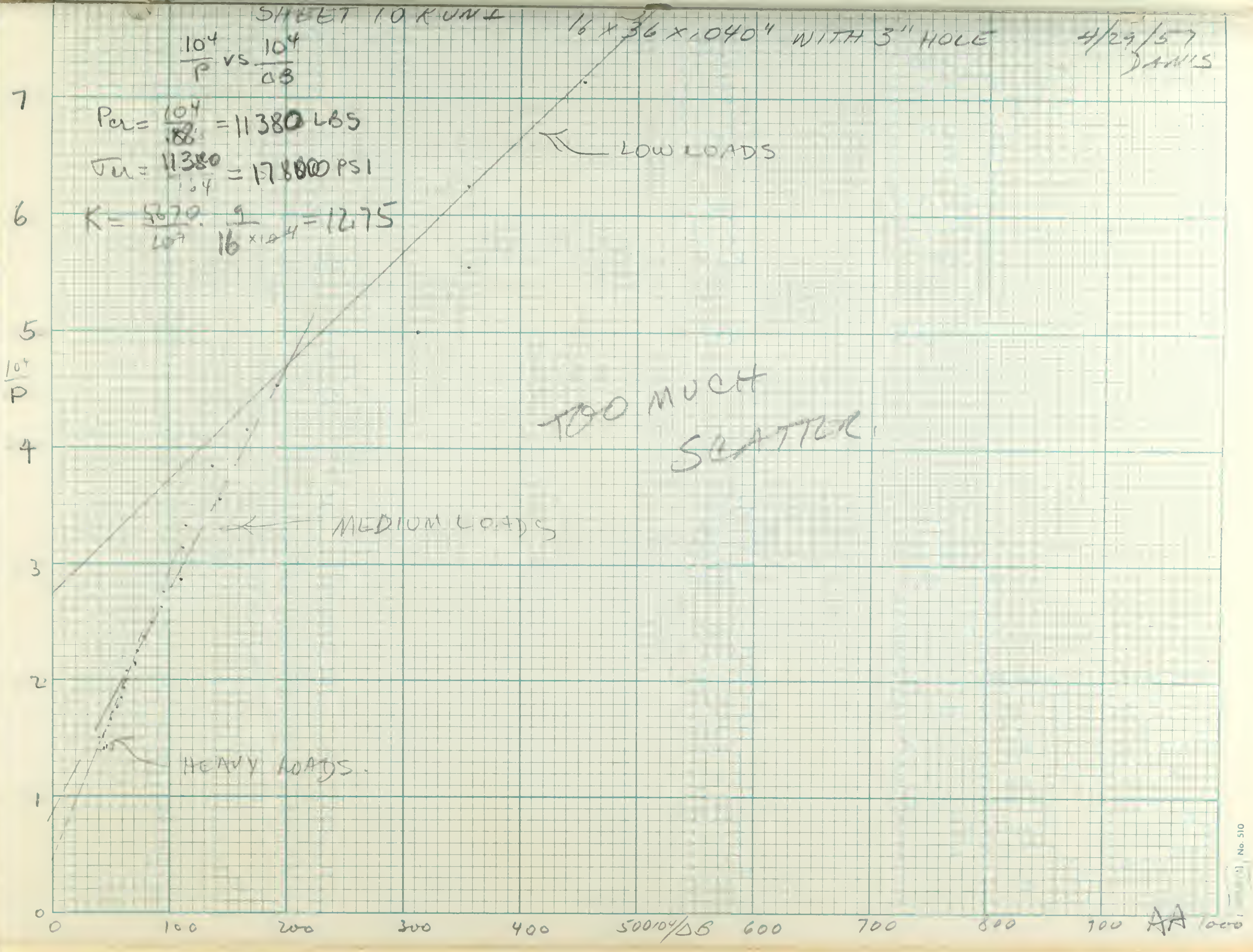
SHEET 10 RUNS 16 × 36 × .040" WITH 3" HOLE 4/29/57 DAVIS

$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta\delta}$

$P_{cr} = \frac{10^4}{.88} = 11380$ LBS

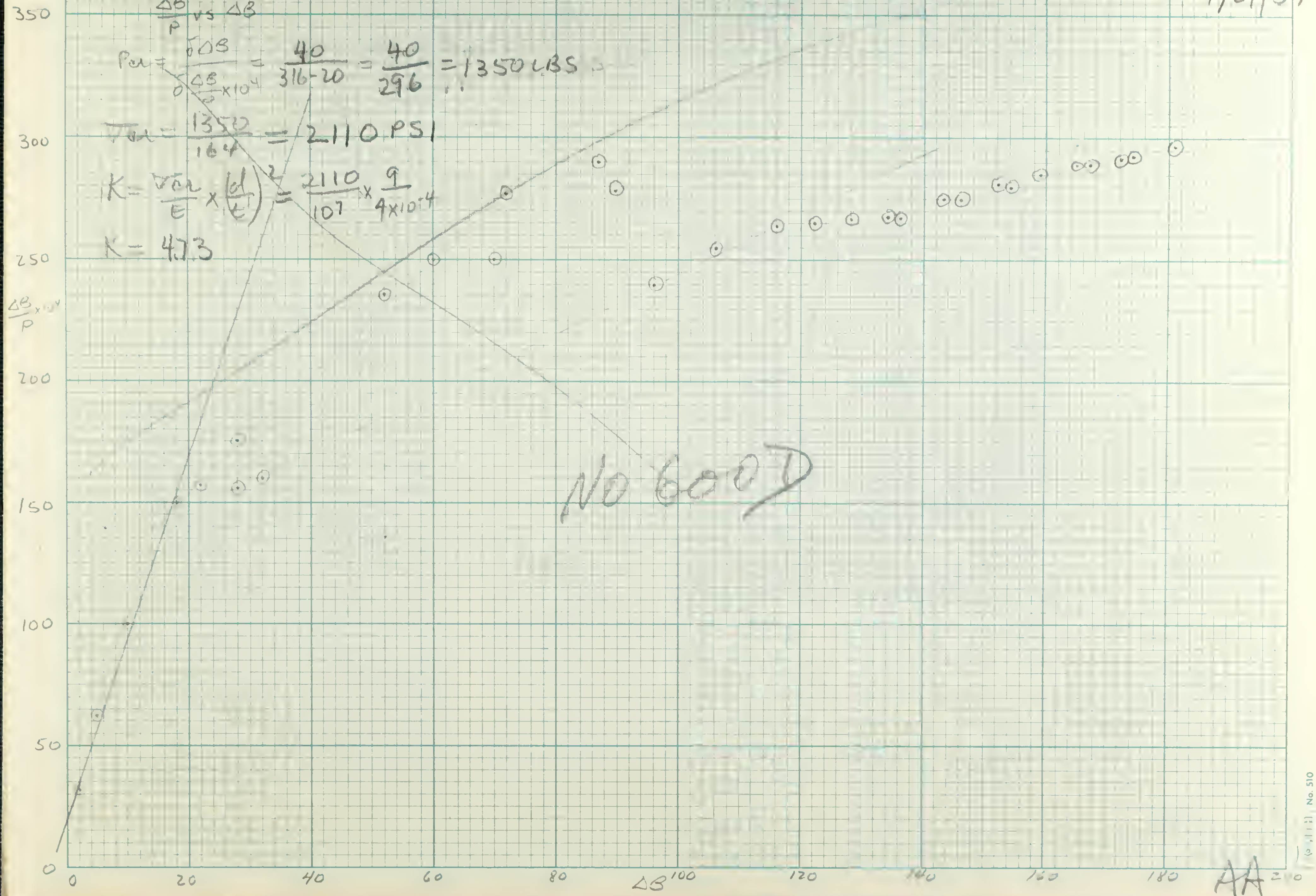
$\sigma_u = \frac{11380}{.64} = 17800$ PSI

$K = \frac{5070}{10^4} \cdot \frac{9}{16 \times 10^{-4}} = 1275$



SHEET 10 RUN 1 24S-T3 ALUMINUM 16X36X.040" WITH 3" HOLE.

4/29/51



$\frac{\Delta B}{P}$ vs ΔB

$P_{cr} = \frac{\delta\Delta B}{\delta\frac{\Delta B}{P}\times10^4} = \frac{40}{316-20} = \frac{40}{296} = 1350$ LBS

$\sigma_{cr} = \frac{1350}{.64} = 2110$ PSI

$K = \frac{\sigma_{cr}}{E}\times\left(\frac{d}{t}\right)^2 = \frac{2110}{10^7}\times\frac{9}{4\times10^{-4}}$

$K = 4.73$

NO GOOD

AA

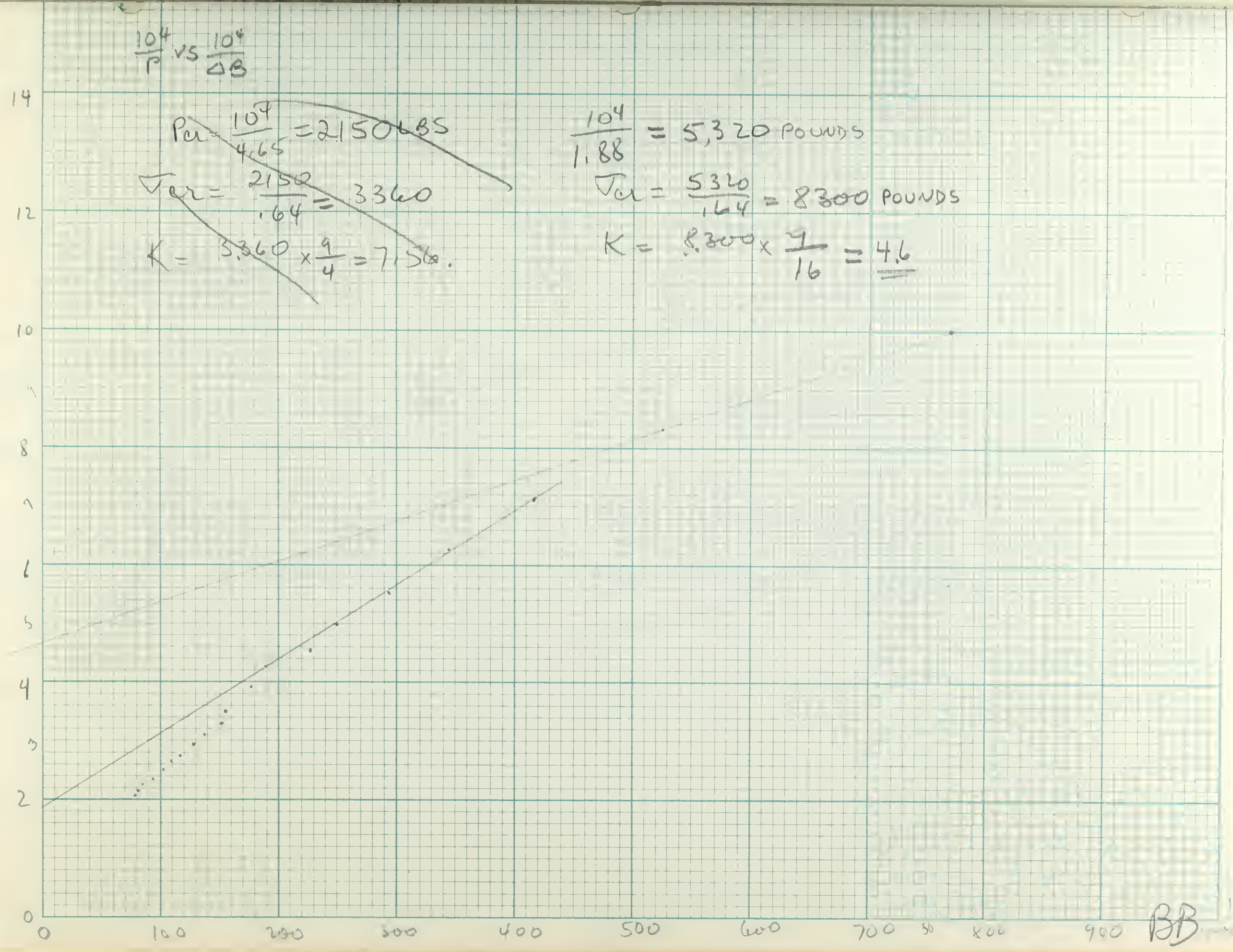
P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}\times 10^4$	$\frac{10^4}{\Delta B}$
0	—↓	634			↓
100	100	637			
200	50	635			
300	33.3	632	2	66.7	5000
400	25	632	2	50	5000
600	16.7	628	6	100	1666
800	12.5	625	9	113	1111
1000	10	621	13	130	769
1200	8.33	615	19	158	526
1400	7.14	610	24	171	417
1600	6.24	605	29	181	345
1800	5.56	600	34	189	294
2000	5.00	594	40	200	250
2200	4.54	590	44	200	227
2400	4.16	582	52	217	192
2600	3.86	578	56	215	179
2800	3.57	570	64	229	156
3000	3.33	568	66	220	152
3200	3.13	561	73	228	137
3400	2.94	555	79	232	127
3600	2.78	548	86	239	116
3800	2.63	543	91	239	110
4000	2.50	538	96	240	104
4200	2.38	528	106	252	94.3
4400	2.27	518	116	264	86.2
4600	2.17	512	122	265	82.0
4800	2.08	506	128	267	78.1

P	$\frac{10^4}{P}$	B	ΔB	$\frac{10^4}{\Delta B}$	$\frac{\Delta B}{P}\times 10^4$
5000	2.00	500	134	74.6	268
5100	1.96	498	136	73.5	267
5200	1.92	491	143	69.9	275
5300	1.89	488	146	68.5	275
5400	1.85	482	152	65.8	281
5500	1.82	480	154	64.9	280
5600	1.78	475	159	62.9	284
5700	1.75	469	165	60.6	289
5800	1.72	467	167	59.9	288
5900	1.69	462	172	58.1	292
6000	1.67	458	176	56.8	293
6100	1.63	453	181	55.2	297
6200	1.61	451	183	54.6	295
6300	1.59	448	186	53.8	295
6400	1.56	441	193	51.8	302
6500	1.54	438	196	51.0	302
6600	1.51	434	200	50.0	303
6700	1.49	431	203	49.2	302
6800	1.47	423	211	47.4	310
6900	1.45	418	216	46.3	313
7000	1.43	411	223	44.8	319

RP-450

BB

$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta B}$



~~$P_{cr} = \frac{10^4}{4.65} = 2150$ LBS~~

~~$\sigma_{cr} = \frac{2150}{.64} = 3360$~~

~~$K = 3360 \times \frac{9}{4} = 7,560.$~~

$\frac{10^4}{1.88} = 5,320$ POUNDS

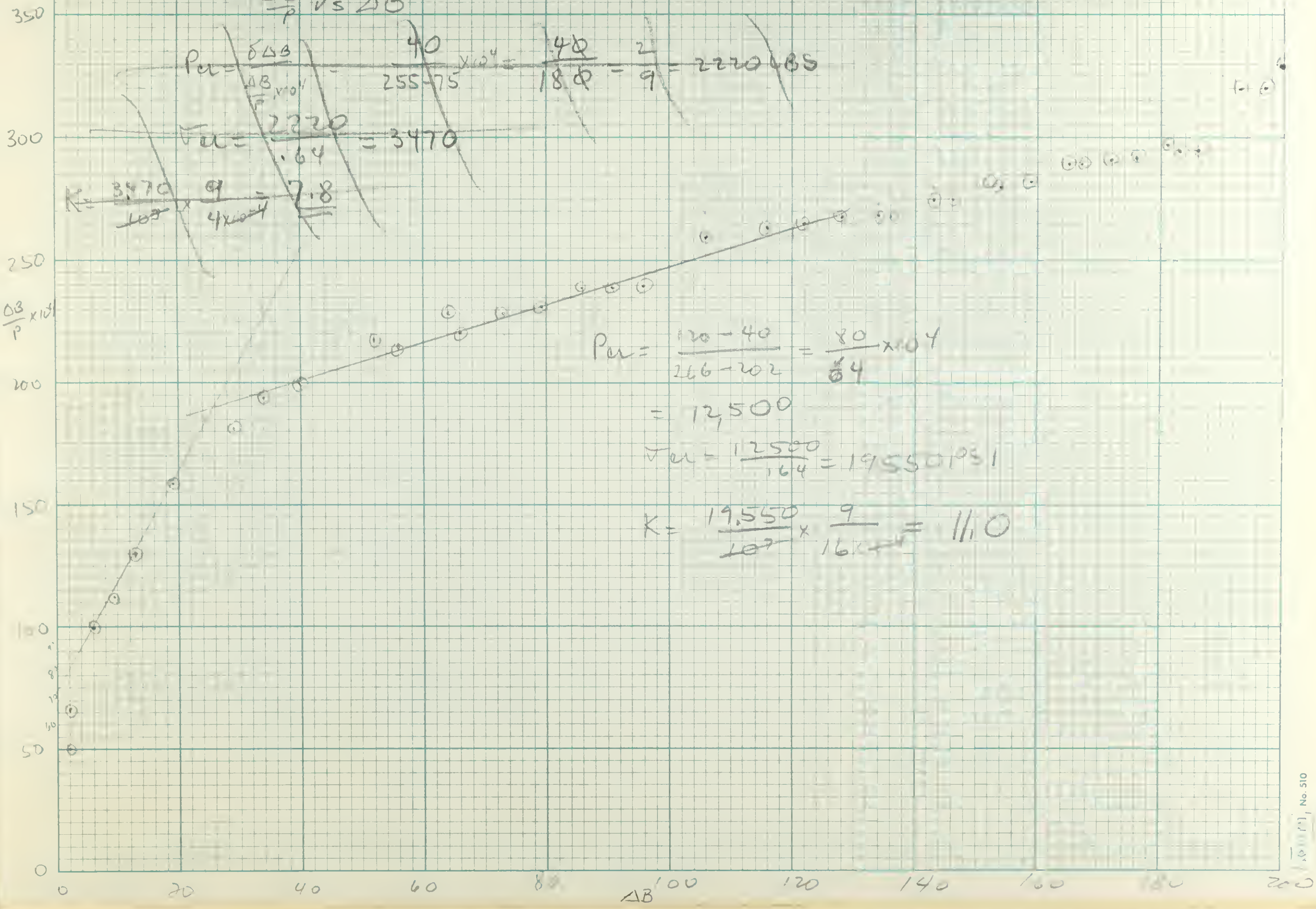
$\sigma_{cr} = \frac{5320}{.64} = 8300$ POUNDS

$K = 8300 \times \frac{7}{16} = \underline{\underline{4.6}}$

SHEET 10 RUN 2 24S-T3 ALUM WITH 3" HOLE 16×36×.040"

5/6/57

$\frac{\Delta B}{P}$ vs ΔB



~~$P_{cr} = \frac{\delta \Delta B}{\frac{\Delta B}{P} \times 10^4} = \frac{40}{255-75} \times 10^4 = \frac{40}{180} = \frac{2}{9} = 2220$ LBS~~

~~$\sigma_{cr} = \frac{2220}{.64} = 3470$~~

~~$K = \frac{3470}{10^7} \times \frac{9}{4 \times 10^{-4}} = 7.8$~~

$P_{cr} = \frac{120-40}{246-202} = \frac{80}{64} \times 10^4$

$= 12,500$

$\sigma_{cr} = \frac{12500}{.64} = 19550$ PSI

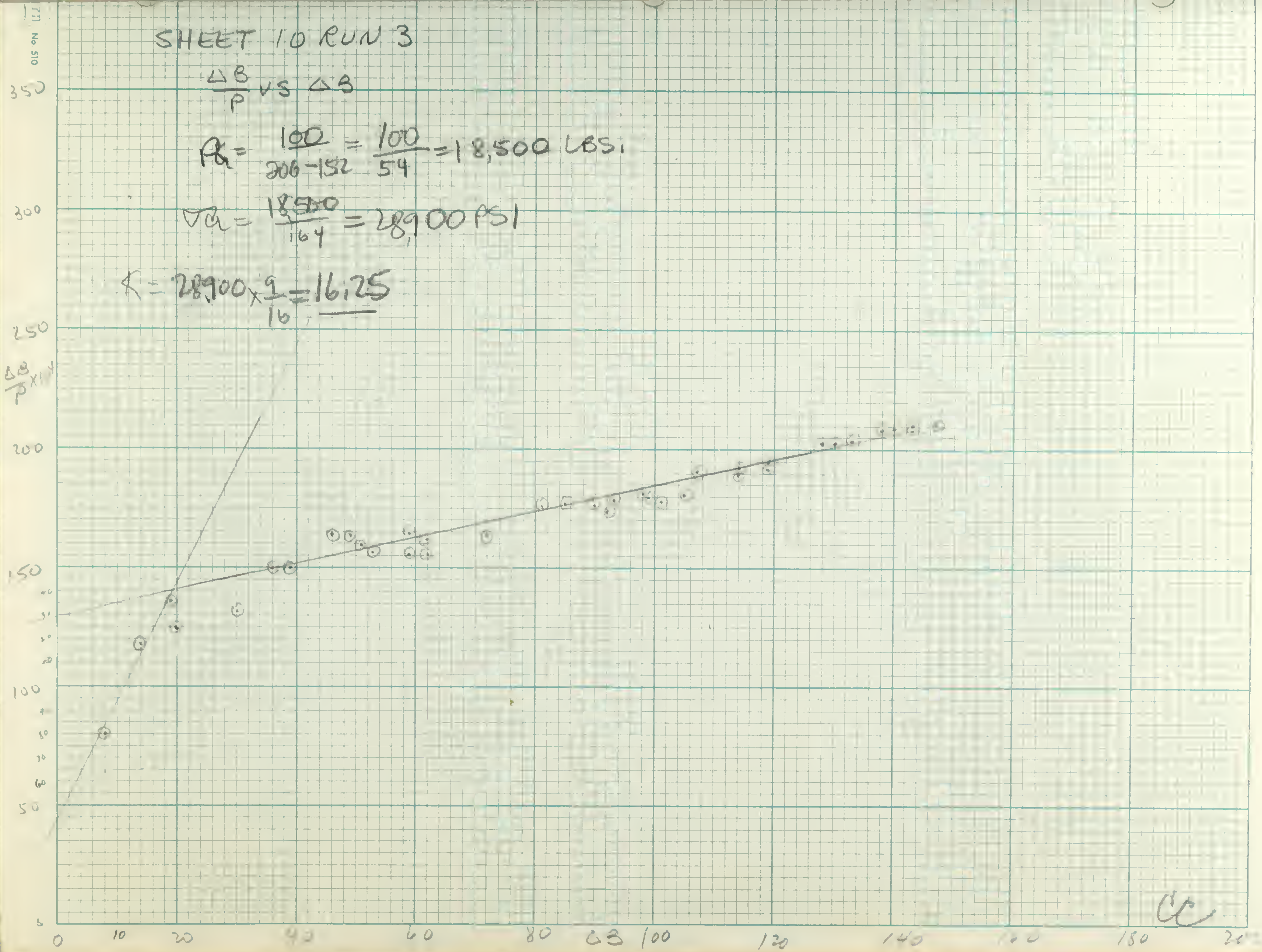
$K = \frac{19,550}{\cancel{10^7}} \times \frac{9}{16 \times 10^{-4}} = 11.0$

SHEET 10 RUNS 76X36X.040 [illegible] T3 ALUMINUM WITH 3" HOLE

P	$\frac{10^4}{P}$	B	ΔB	[illegible]	[illegible]
0	—	701	—		
100	100	701	—		
200	50	702	—		
300	33.3	701	—		
400	25	701	—		
[illegible]	16.7	700	1		104
[illegible]	12.5	700	1		104
[illegible]	10	693	8	80	1250
[illegible]	8.33	687	14	117	714
[illegible]	7.14	682	19	136	526
[illegible]	6.24	681	20	125	500
[illegible]	5.56	678	23	128	435
[illegible]	5	676	25	125	400
[illegible]	4.54	672	29	132	345
[illegible]	4.16	665	36	150	278
[illegible]	3.86	662	39	150	256
[illegible]	3.57	655	46	164	217
[illegible]	3.33	658	49	163	233
[illegible]	3.13	650	51	159	196
[illegible]	2.94	648	53	156	188
3600	2.78	[illegible]	59	164	169
[illegible]	2.63	642	59	155	169
[illegible]	2.50	636	65	163	154
[illegible]	2.38	636	65	155	154
[illegible]	2.27	621	72	164	139
[illegible]	2.17	620	81	176	123
[illegible]	2.08	616	85	177	118

P	$10^4/P$	B′	$\overset{\downarrow}{\Delta B}$	$\frac{\Delta B}{P}\times 10^{4}$	[illegible]
5000	2	612	89	178	112
5100	1.96	611	90	176	111
5200	1.92	608	93	179	108
5300	1.89	604	92	174	109
5400	1.85	603	98	181	102
5500	1.82	602	99	180	101
[illegible]	1.78	594	107	191	93.4
[illegible]	1.75	600	101	177	99
[illegible]	1.72	596	105	181	95.2
[illegible]	1.69	587	114	193	87.7
[illegible]	1.67	587	114	190	87.8
[illegible]	1.63	582	119	195	84.0
[illegible]	1.61	582	119	192	84.0
[illegible]	1.59	573	128	203	78.1
[illegible]	1.56	571	130	203	76.9
[illegible]	1.54	568	133	204	75.1
[illegible]	1.51	[illegible]	138	209	72.5
[illegible]	1.49	561	140	209	71.4
[illegible]	1.47	[illegible]	143	210	69.9
[illegible]	1.45	558	143	207	69.9
[illegible]	1.43	554	147	210	68.0

SHEET 10 RUN 3CC



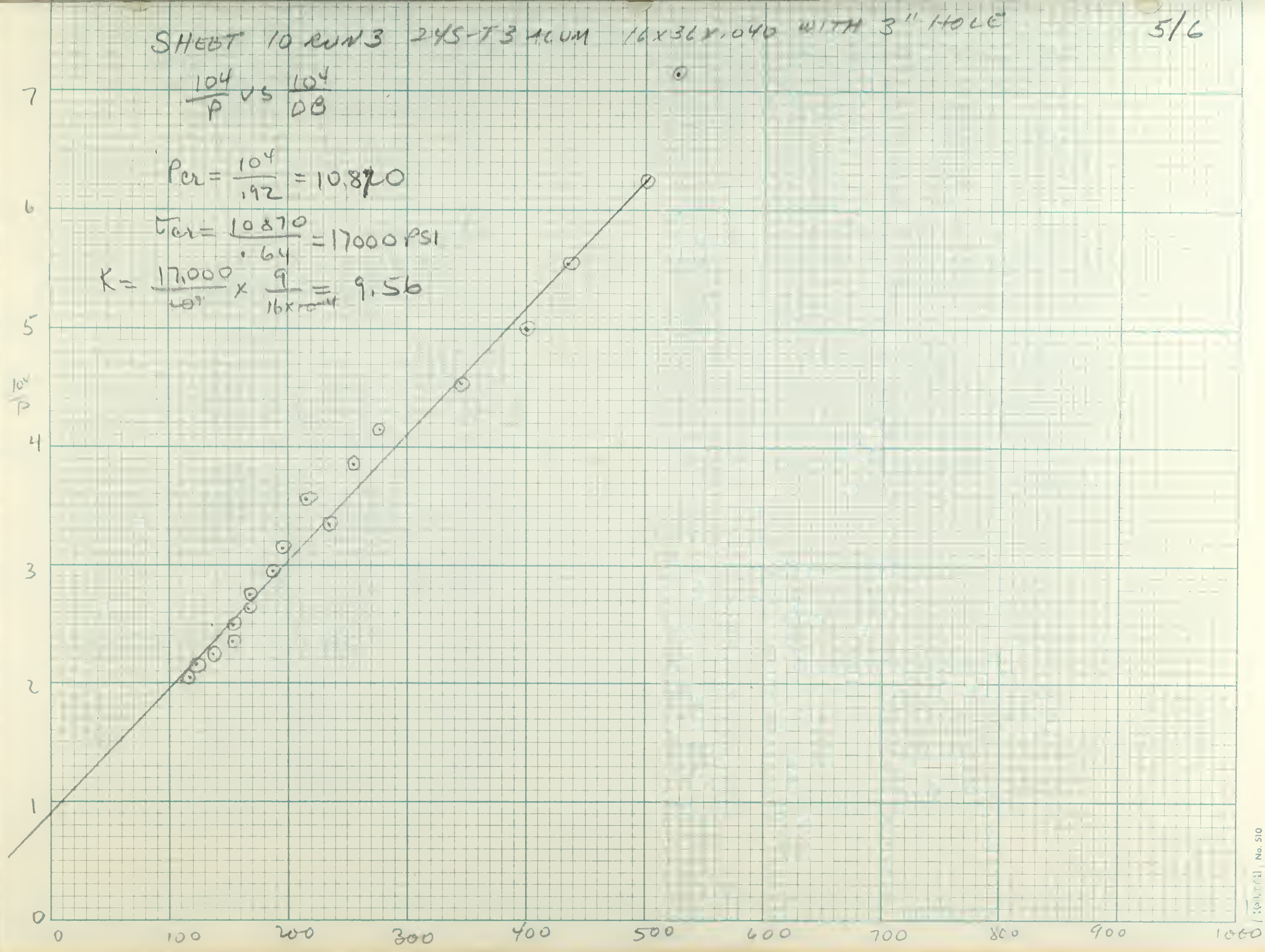
SHEET 10 RUN 3

$\frac{\Delta B}{P}$ vs ΔB

$P_a = \frac{100}{206-152} = \frac{100}{54} = 18{,}500$ LBS.

$\sigma_a = \frac{18500}{164} = 28{,}900$ PSI

$K = 28{,}900 \times \frac{9}{16} = \underline{16{,}25}$



SHEET 10 RUN 3 24S-T3 ALUM 16 x 36 x .040 WITH 3" HOLE

$\frac{10^4}{P}$ vs $\frac{10^4}{\delta\theta}$

$P_{cr} = \frac{10^4}{.92} = 10{,}870$

$\tau_{cr} = \frac{10870}{.64} = 17000$ PSI

$K = \frac{17{,}000}{10^7} \times \frac{9}{16 \times 10^{-4}} = 9.56$

No. 510

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}\times 10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
0	↓	1518			↓	340		
100	100	1499	19	1900	526	398		
200	50	1499	19	950	526	459		
300	33.3	1494	24	800	417	521		
400	25	1482	36	900	278	572		
500	20	1464	54	508	185	632		
600	16.7	1432	86	1433	116	690		
700	14.3	1400	118	1685	84.7	750		
800	12.5	1342	176	2200	56.8	818		
900	11.1	1275	243	2700	41.2	879		
1000	10.0	1189	329	3290	30.4	945		
1100	9.09	1093	425	3860	23.5	1008		
1200	8.33	986	532	4430	18.8	1172		
1300	7.69	876	642	4940	15.6	1139		
1400	7.14	772	746	5330	13.4	1200		
1500	6.67	658	860	5730	11.6	1267		
1600	6.24	546	972	6080	10.3	1332		
1700	5.88	442	1076	6330	9.30	1395		
1800	5.56	327	1191	6620	8.39	1463		
1900	5.76	231	1287	6770	7.79	1528		
2000	5.00	128	1390	6950	7.19	1595		
2100	4.76	18	1500	7142	6.67	1666		
2200	4.54	1925	1593	7240	6.27	1725		
2300	4.35	1819	1699	7390	5.88	1799		
2400	4.16	1722	1796	7480	5.56	1864		
2500	4.00	1620	1898	7590	5.27	1937		

±P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}\times 10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
2600	3.84	1524	1994	7670	5.01	2002		
2700	3.70	1435	2083	7710	4.79	2073		
2800	3.57	1347	2171	7750	4.60	2142		
2900	3.44	1260	2258	7790	4.42	2208		
3000	3.33	1168	2350	7830	4.26	2280		
3100	3.23	1082	2436	7860	4.10	2349		
3200	3.13	1000	2518	7870	3.96	2416		
3300	3.03	905	2613	7920	3.83	2488		
3400	2.94	825	2693	7920	3.70	2558		
3500	2.86	735	2783	7951	3.59	2632		
3600	2.78	652	2866	7961	3.49	2700		
3700	2.70	567	2951	7980	3.38	2772		
3800	2.63	482	3036	7990	3.29	2849		
3900	2.56	400	3118	7990	3.20	2918		
4000	2.50	310	3208	8020	3.12	3000		

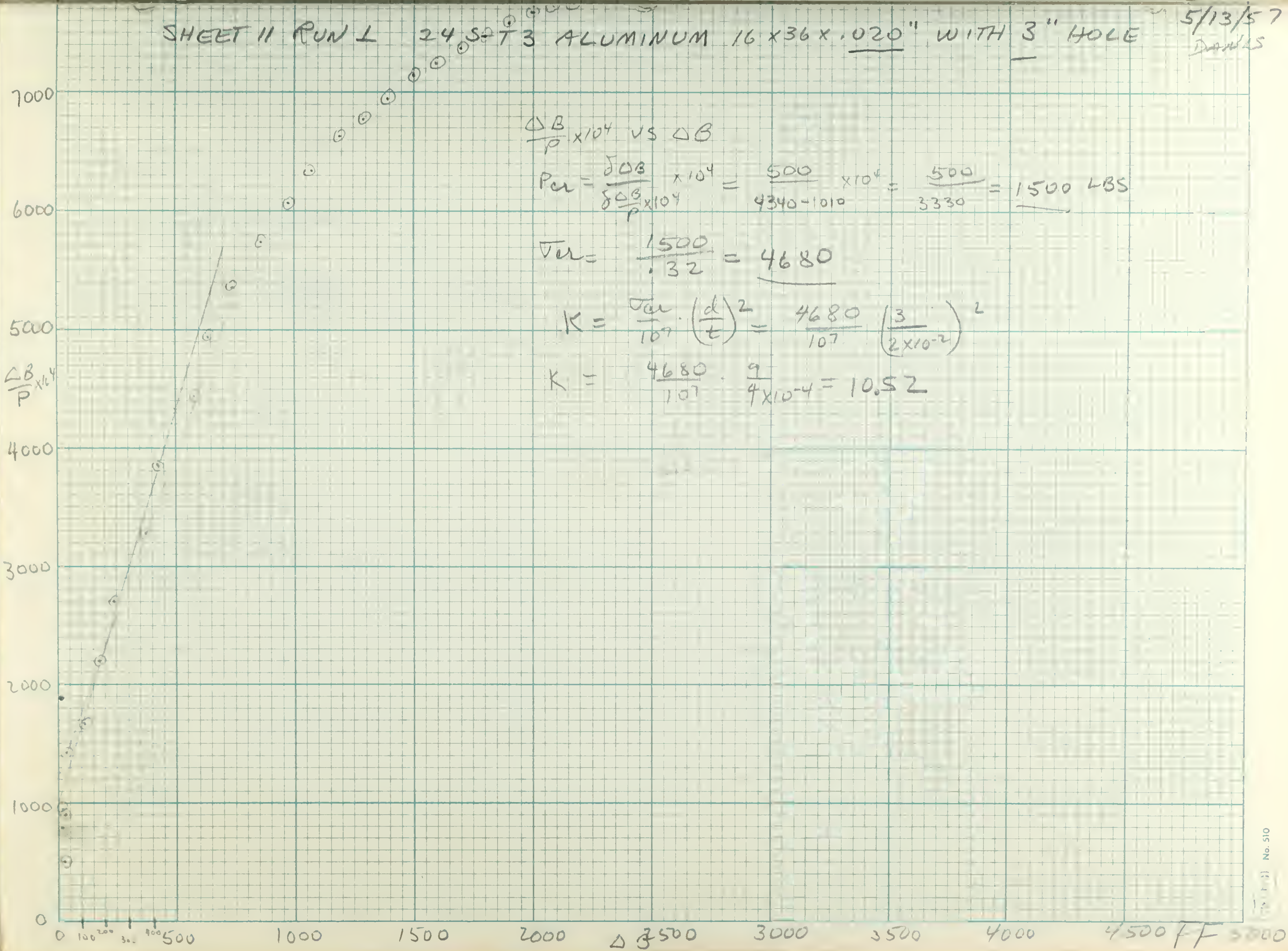
FF

50000PSI $\times$ .020 $\times$ 16 = .32 $\times$ 5×10^4 = 1.6×10^4

$\frac{16{,}000}{3}$ LBS LOAD = 5333 LBS LOAD TO
CAUSE YIELD AT
MAX STRESS POINT
ON HOLE

SHEET 11 RUN 1 24S-T3 ALUMINUM 16 x 36 x .020" WITH 3" HOLE

5/13/57
DAWES



$\frac{\Delta B}{P}\times10^4$ VS ΔB

$$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P}\times10^4}\times10^4 = \frac{500}{4340-1010}\times10^4 = \frac{500}{3330} = 1500 \text{ LBS}$$

$$\sigma_{cr} = \frac{1500}{.32} = 4680$$

$$K = \frac{\sigma_{cr}}{10^7}\cdot\left(\frac{d}{t}\right)^2 = \frac{4680}{10^7}\left(\frac{3}{2\times10^{-2}}\right)^2$$

$$K = \frac{4680}{10^7}\cdot\frac{9}{4\times10^{-4}} = 10.52$$

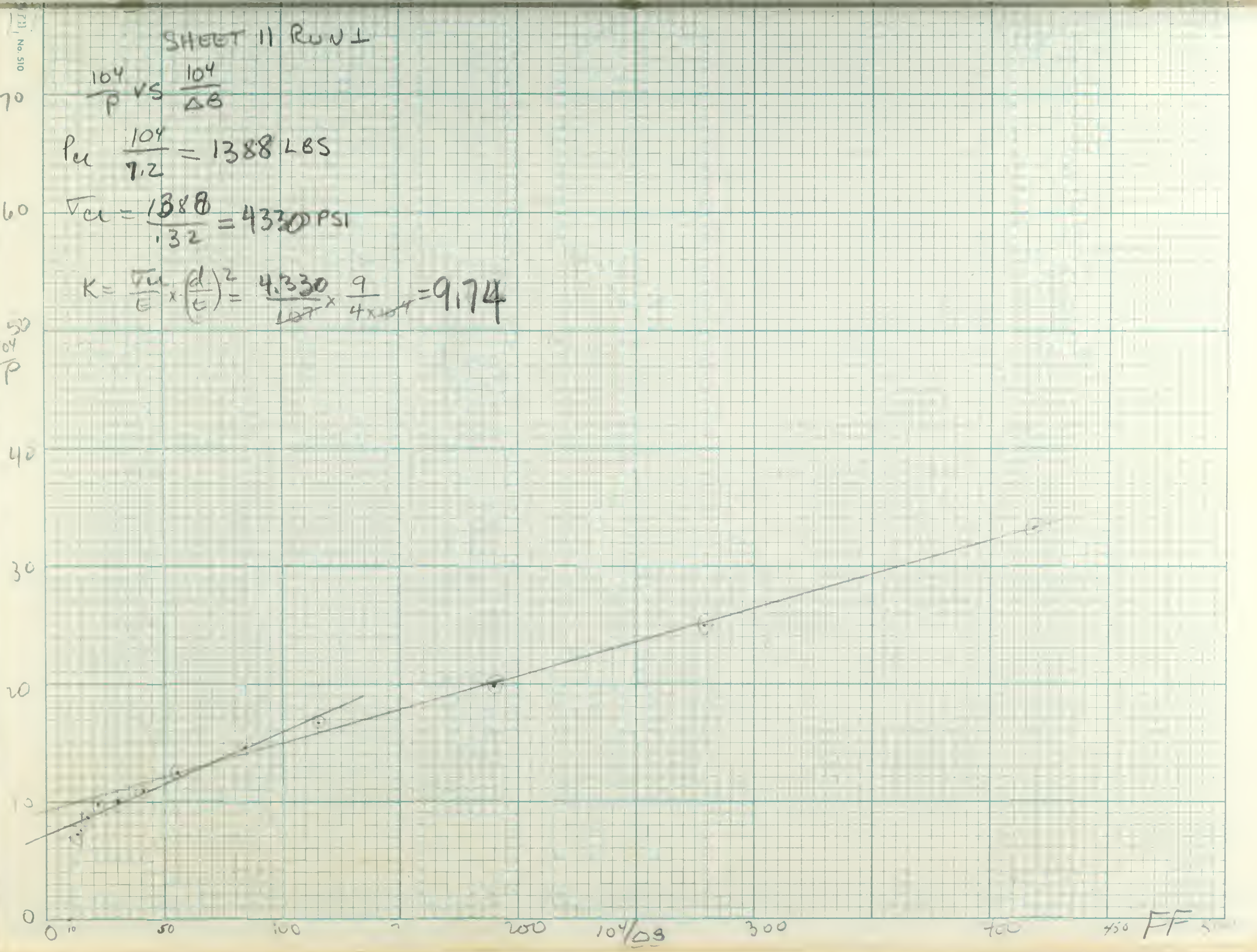
SHEET 11 RUN 1

$\frac{10^4}{P}$ VS $\frac{10^4}{\Delta}$

P_{cr} $\frac{10^4}{7.2} = 1388$ LBS

$\sigma_{cr} = \frac{1388}{.32} = 4330$ PSI

$K = \frac{\sigma_{cr}}{E} \times \left(\frac{d}{t}\right)^2 = \frac{4330}{10^7} \times \frac{9}{4 \times 10^{-4}} = 9.74$



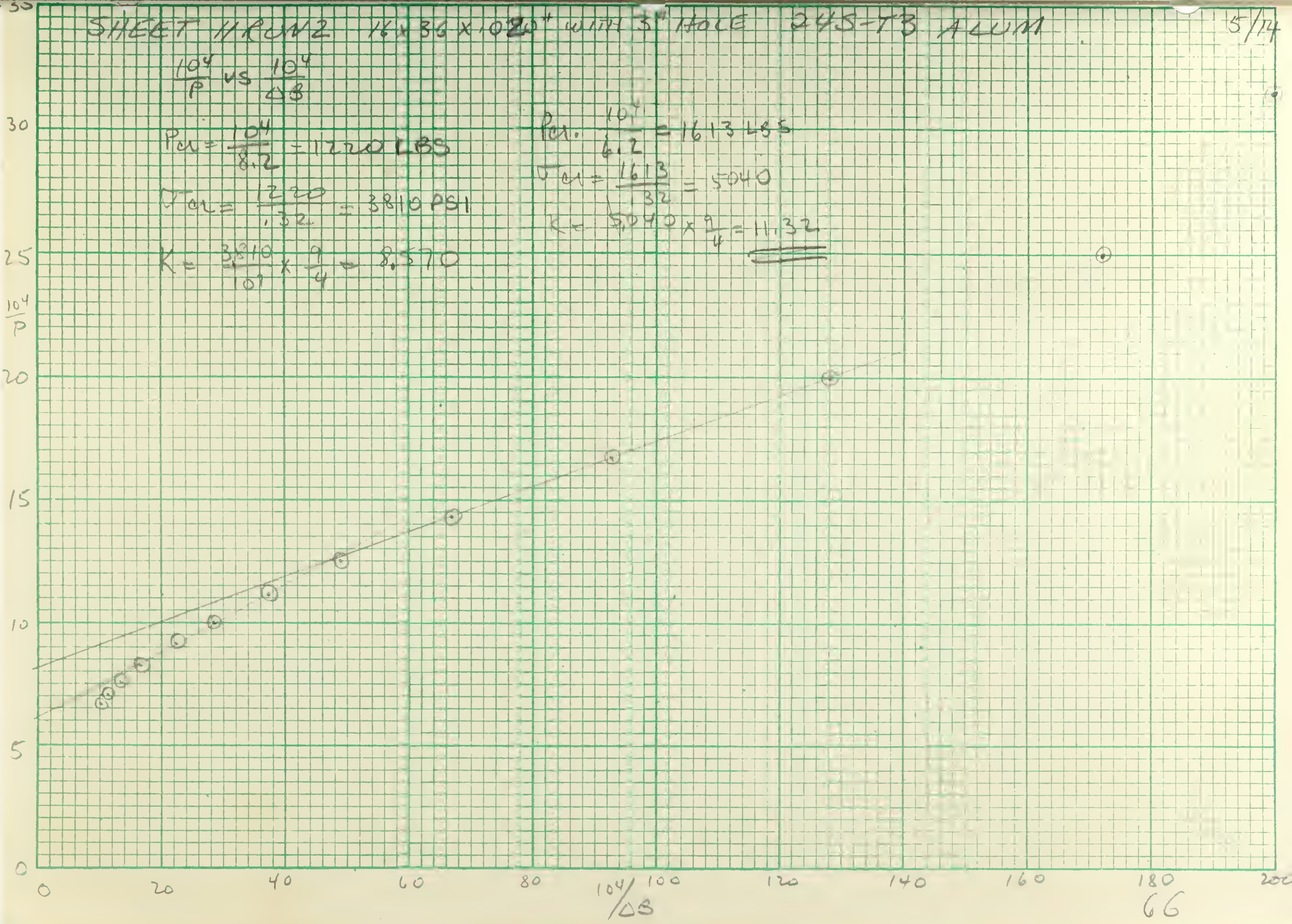
No. 510

P	$\frac{10^4}{P}$	K	ΔB	$\frac{\Delta B}{P}\times10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
0		2530				300		
100	100	2490	40	4000	250	370		
200	50	2488	42	2100	238	430		
300	33	2480	50	1670	200	490		
400	25	2472	58	1450	172	558		
500	20	2452	78	1560	128	618		
600	16.7	2422	108	1800	92.6	685		
700	14.3	2380	150	2140	66.7	752		
750		2362	168	2240	59.5	762		
800	12.5	2325	[illegible]	2560	49.0	812		
850		2300	230	2710	43.5	840		
900	11.1	2264	266	2960	37.6	~~861~~		
950		2219	311	3270	32.2	908		
1000	10.0	2175	355	3550	28.2	941		
1050		2139	391	3720	25.6	965		
1100	9.09	2081	449	4080	22.3	1005		
1150		1982	548	4770	21.0	1038		
1200	8.33	1931	599	14990	16.7	1069		
1250		1872	658	5260	15.2	1102		
1300	7.69	1791	739	5680	13.5	1138		
1400	7.14	1666	864	6170	11.6	1201		
1500	6.67	1558	972	6480	10.3	1268		
1600	6.24	1452	1078	6740	9.26	1335		
1700	5.88	1330	1200	7060	8.33	1405		
1800	5.56	1222	1308	7270	7.63	1472		
1900	5.76	1096	1434	7550	6.99	1534		

P	$\frac{10^4}{P}$	B	ΔB	$\frac{\Delta B}{P}\times10^4$	$\frac{10^4}{\Delta B}$	T	ΔT	STRESS
2000	5.00	1028	1502	7510	6.67	1600		
2100	4.76	912	1618	7700		1675		
2200	4.54	818	1712	7780		1741		
2300	4.35	720	1810	7870		1810		
2400	4.16	622	1908	7950		1880		
2500	4.00	515	2015	8060		1952		
2600	3.84	435	2095	8060		2020		
2700	3.70	318	2212	8190		2089		
2800	3.57	218	2312	8260		2160		
2900	3.44	142	2388	8230		2228		
3000	3.33	045	2485	8280		2315		

SHEET #RCW2 16 x 36 x .020" WITH 3" HOLE 24S-T3 ALUM 5/14

$\frac{10^4}{P}$ vs $\frac{10^4}{\Delta B}$



$P_{cr} = \frac{10^4}{8.2} = 1220$ LBS

$\sigma_{cr} = \frac{1220}{.32} = 3810$ PSI

$K = \frac{3810}{10^7} \times \frac{9}{4} = 8.570$

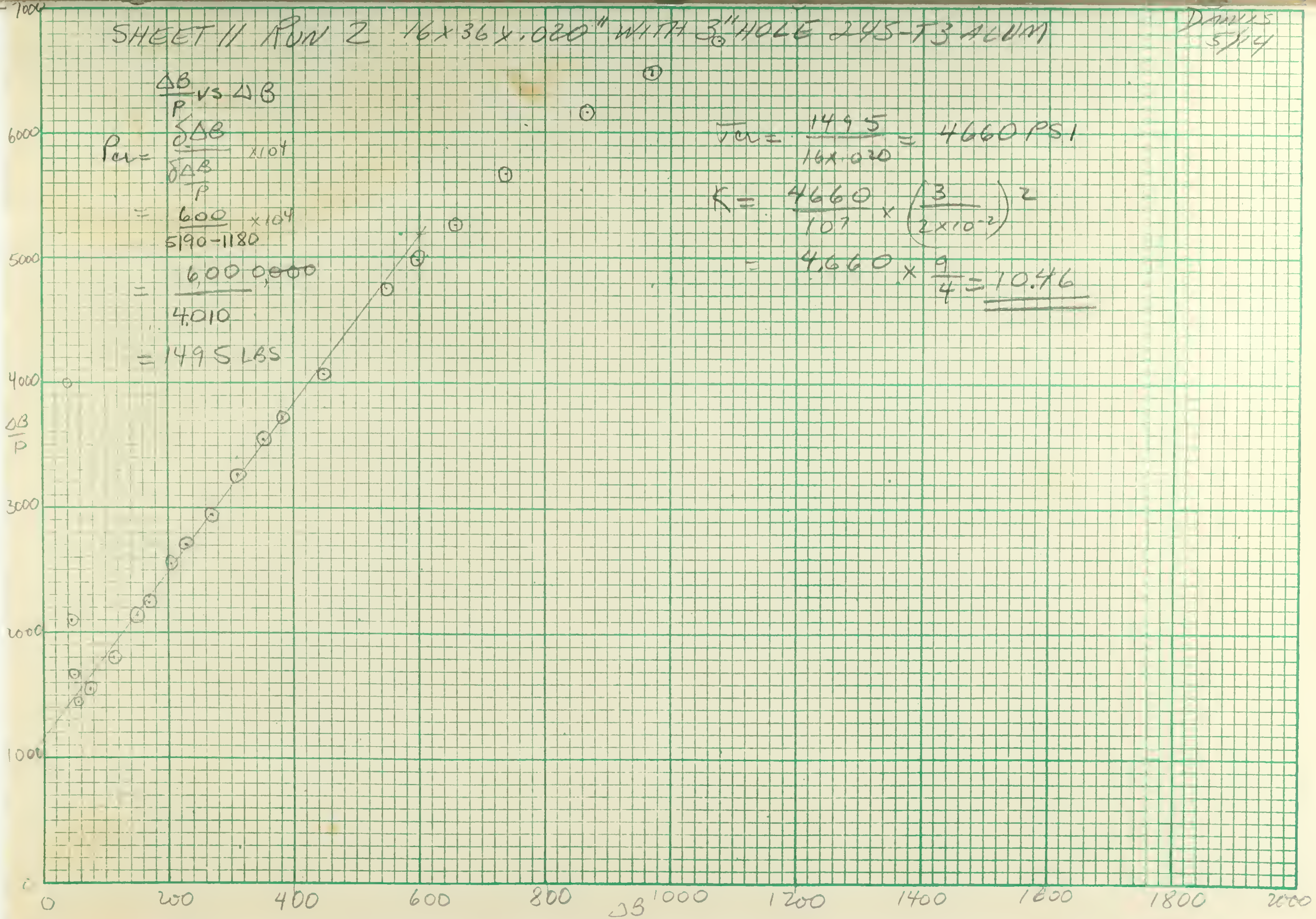
$P_{cr} \cdot \frac{10^4}{6.2} = 1613$ LBS

$\sigma_{cr} = \frac{1613}{.32} = 5040$

$K = 5040 \times \frac{9}{4} = 11.32$

SHEET 11 RUN 2 16 x 36 x .020" WITH 3" HOLE 24S-T3 ALUM

DAVIES
5/14



$\frac{\Delta B}{P}$ VS ΔB

$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P}} \times 10^4$

$= \frac{600}{5190-1180} \times 10^4$

$= \frac{6{,}000{,}000}{4{,}010}$

$= 1495$ LBS

$\sigma_{cr} = \frac{1495}{16 \times .020} = 4660$ PSI

$K = \frac{4660}{10^7} \times \left(\frac{3}{2 \times 10^{-2}}\right)^2$

$= 4{,}660 \times \frac{9}{4} = \underline{\underline{10.46}}$

GG

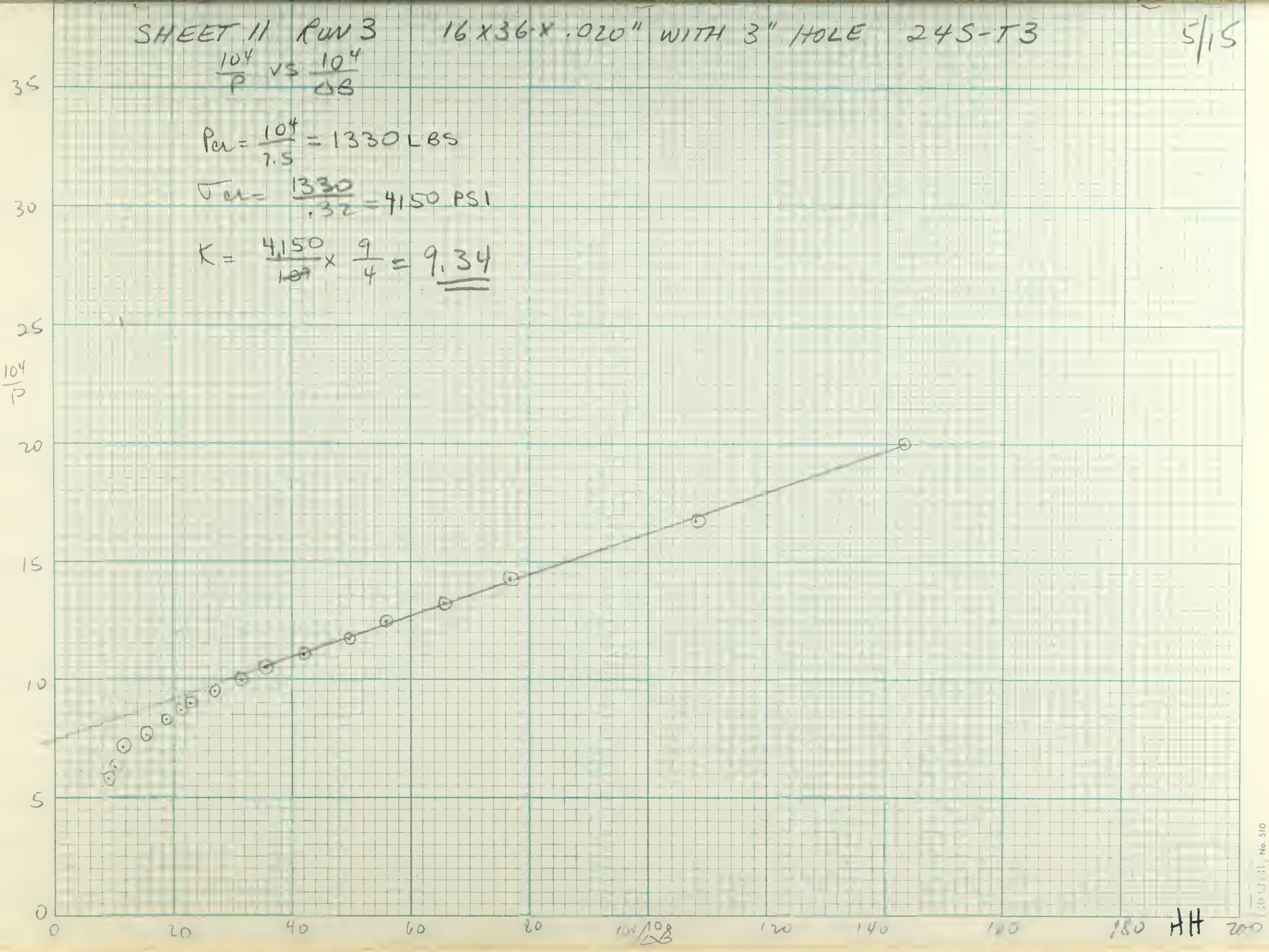
P	/P	D	ΔD	F	[illegible]
0		2430	—		
100	100	2396	34	3400	294
200	50	2395	35	1750	286
300	33.3	2395	35	1170	286
400	25	2382	48	1200	208
500	20	2360	70	1400	143
600	16.7	2338	92	1530	108
700	14.3	2300	130	1860	76.9
750	13.3	2278	152	2026	65.8
800	12.5	2251	179	2240	55.9
850	11.7	2228	202	2380	47.5
900	11.1	2192	238	2640	42.0
950	10.5	2151	279	2940	35.8
1000	10.0	2114	316	3160	31.6
1050	9.52	2062	368	3500	27.1
1100	9.09	2003	437	3970	22.9
1150	8.69	1968	462	4010	21.6
1200	8.33	1902	528	4400	18.9
1300	7.69	1794	636	4890	15.7
1400	7.14	1685	745	5320	13.4
1500	6.67	1570	860	5730	11.6
1600	6.24	1458	972	6060	10.3
1700	5.88	1350	1080	6350	9.26
1800	5.56	1237	1197	6650	8.35
1900	5.26	1132	1298	6830	7.70
2000	5.00	1028	1402	7001	7.13

P	/P	D	ΔD	F	[illegible]
2100	4.76	924	1506	7180	6.64
2200	4.54	826	1604	7290	6.23
2300	4.35	732	1698	7380	5.89
2400	4.16	636	1794	7480	5.57
2500	4.00	538	1892	7580	5.29
2600	3.84	441	1989	7650	5.03
2700	3.70	349	2081	7720	4.81
2800	3.57	251	2179	7820	4.57
2900	3.44	168	2262	7820	4.42
3000	3.33	62	2368	7900	4.22

HH

SHEET 11 RUN 3 16 X 36 X .020" WITH 3" HOLE 24S-T3 5/15

$\frac{10^4}{P}$ VS $\frac{10^4}{\Delta B}$



$P_{cr} = \frac{10^4}{7.5} = 1330$ LBS

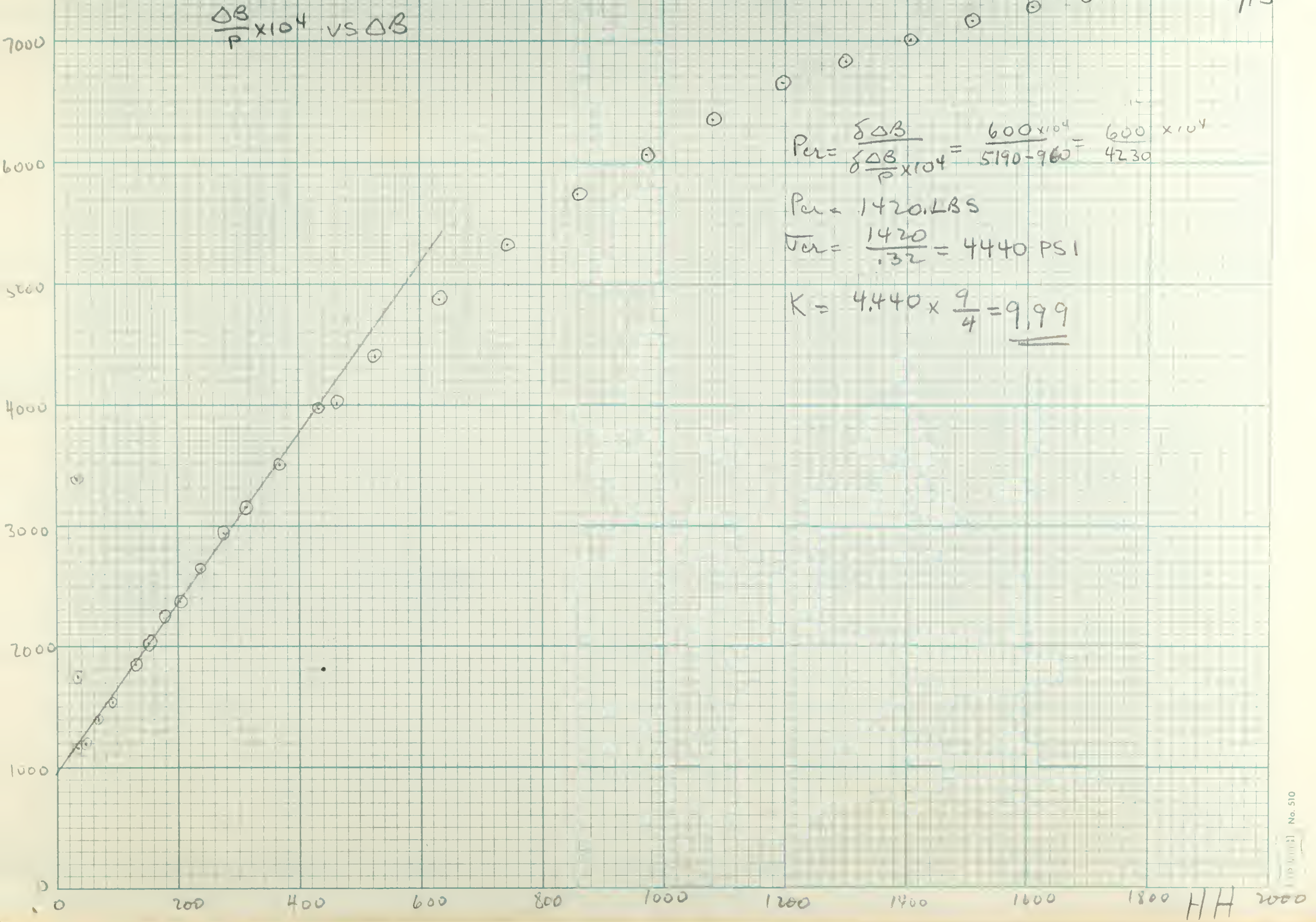
$\sigma_{cr} = \frac{1330}{.32} = 4150$ PSI

$K = \frac{4150}{10^3} \times \frac{9}{4} = \underline{\underline{9.34}}$

SHEET 11 RUN3 24S-T3 ALUM 16X36X.020" WITH 3" HOLE

5/15

$\frac{\Delta B}{P} \times 10^4$ VS ΔB



$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P} \times 10^4} = \frac{600 \times 10^4}{5190-960} = \frac{600}{4230} \times 10^4$

$P_{cr} = 1420.$ LBS

$\sigma_{cr} = \frac{1420}{.32} = 4440$ PSI

$K = 4.440 \times \frac{9}{4} = \underline{\underline{9.99}}$

P	$\frac{10}{P}$	B	ΔB	$\frac{}{P}$	$\frac{}{\Delta B}$
0		1182			
100		1150			
200		1141			
300		1152			
400		1168			
500		1225			
600		1282			
700		1360			
800		1442			
900		1511			
1000		1588			
1100		1662			
1200		1715			
1300		1768			
1400		1801			
1500		1830			
1600		1856			
1700		1856			
1800	5.56	1855	0	–	
1900	5.76	1850	5	263	2000
2000	5.00	1828	27	135.	370

P	ρ	B	ΔB	$\frac{}{P}$	$\frac{}{\Delta B}$	ΔD	$\frac{}{P}\times 10$
2100	4.76	1810	45	214	222		
2200	4.54	1773	82	373	122		
2300	4.35	1732	123	534	81.3		
2400	4.16	1685	170	708	58.8		
2500	4.00	1624	231	924	43.3		
2600	3.84	1572	283	1088	35.3		
2700	3.70	1499	356	1320	28.1		
2800	3.57	1422	433	1550	23.1		
2900	3.44	1368	487	1680	20.5		
3000	3.33	1315	540	1800	18.5		
3100	3.23	1270	585	1887	17.1		
3200	3.13	1238	617	1928	16.2		
3300	3.03	1209	646	1957	15.5		
3400	2.94	1196	659	1938	15.2		
3500	2.86	1174	681	1945	14.7	8	22.5
3600	2.78	1156	699	1941	14.3	26	72.2
3700	2.70	1145	710	1918	14.1	37	100
3800	2.63	1132	723	1902	13.8	50	132
3900	2.56	1112	743	1905	13.4	60	154
4000	2.50	1100	755	1887	13.2	82	205

II

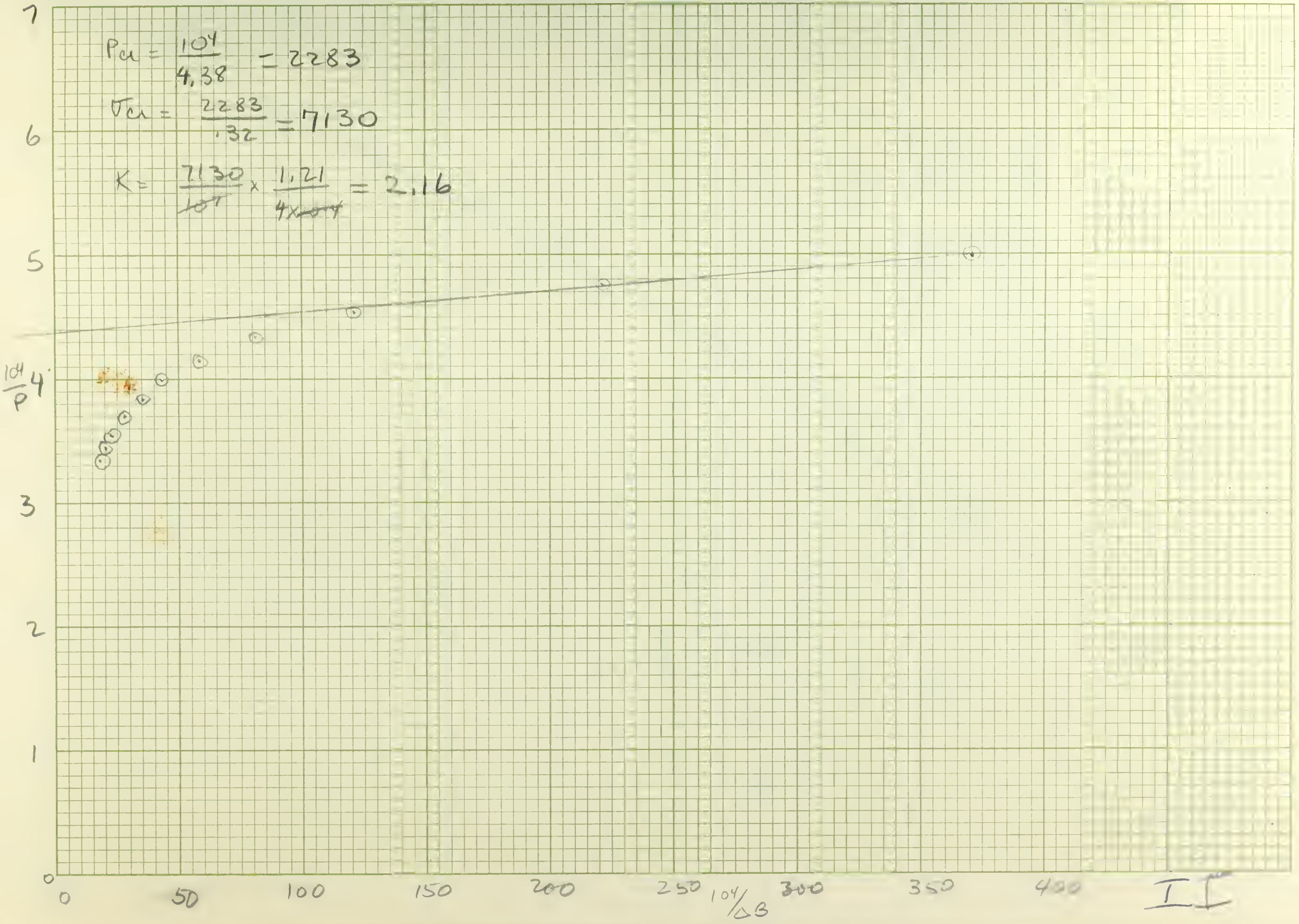
$P = \tau A$

$P = \frac{50000}{3} \times .020 \times 16$

$P = \frac{5000\cancel{0}}{\cancel{3}} \times \overset{10}{\cancel{.32}}$ lbs $\underline{\underline{\text{max}}}$

USE 4,000

SHEET 12 RUN ⊥ 16X36X.020" 24S-T3 ALUM WITH 1.1" HOLE 5/17



$P_{cr} = \frac{10^4}{4,38} = 2283$

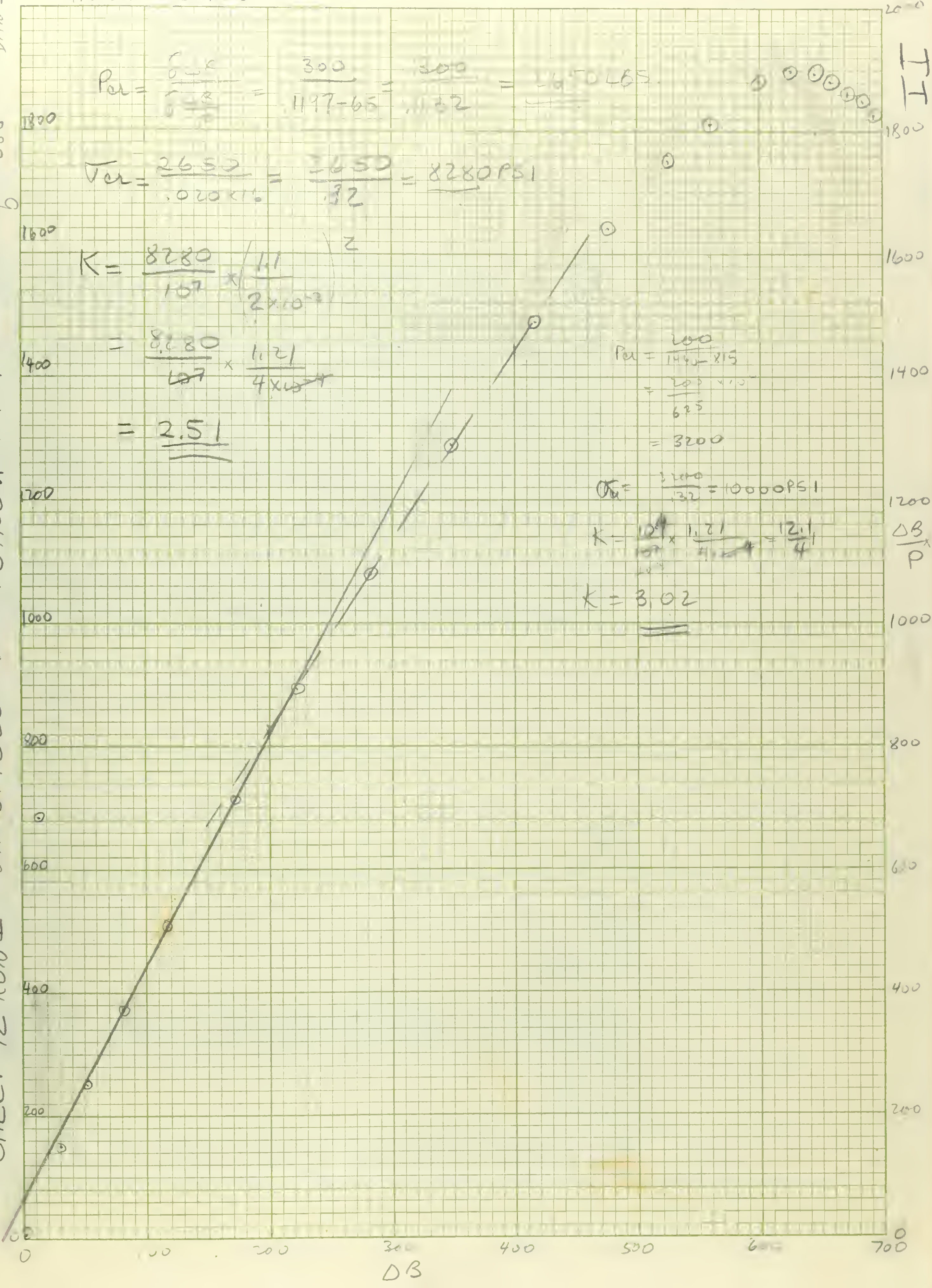
$\sigma_{cr} = \frac{2283}{.32} = 7130$

$K = \frac{7130}{\cancel{10^7}} \times \frac{1.21}{4\times\cancel{.0004}} = 2.16$

SHEET 12 RUN 1 1.1" HOLE .020" THICK - 5/17

SHEET 12 RUN 1 16 x 30 x .020" 24S-T3 ALUM WITH 1.1" HOLE $\frac{1}{b}$ .0688

3/11 DAVIS



$P_{cr} = \frac{[illegible]}{[illegible]} = \frac{300}{1197-65} = \frac{300}{.132} =$ [illegible] LBS

$\sigma_{cr} = \frac{2650}{.020 \times 16} = \frac{2650}{.32} = 8280$ PSI

$K = \frac{8280}{10^7} \times \left(\frac{1.1}{2 \times 10^{-2}}\right)^2$

$= \frac{8280}{\cancel{10^7}} \times \frac{1.21}{4 \times \cancel{10^{-4}}}$

$= \underline{\underline{2.51}}$

$P_{cr} = \frac{200}{1440-815}$

$= \frac{200 \times 10}{625}$

$= 3200$

$\sigma_{cr} = \frac{3200}{.32} = 10000$ PSI

$K = \frac{10^4}{10^7} \times \frac{1.21}{4 \times 10^{-4}} = \frac{12.1}{4}$

$\underline{\underline{K = 3.02}}$

P	/P	D	ΔD	P̄	ΔB
0		1202			
100		1180			
200		1172			
300		1176			
400		1212			
500		1262			
600		1312			
700		1390			
800		1472			
900		1542			
1000		1618			
1100		1688			
1200		1753			
1300		1802			
1400		1842			
1500		1875			
1600		1892			
1700		1905	0	-	
1800	5.56	1904	1	6	
1900	5.76	1892	13	684	769
2000	5.00	1875	30	150	333

P	/P	D	ΔD	P̄	ΔB
2100	4.76	1862	53	252	189
2200	4.54	1823	82	373	122
2300	4.35	1788	117	508	85.5
2400	4.16	1733	172	716	58.1
2500	4.00	1682	223	892	44.9
2600	3.84	1623	282	1080	35.5
2700	3.70	1556	349	1290	28.6
2800	3.57	1489	416	1490	24.0
2900	3.44	1429	476	1640	21.0
3000	3.33	1380	525	1750	19.0
3100	3.23	1345	560	1810	17.8
3200	3.13	1305	600	1880	[illegible]
3300	3.03	1279	626	1896	16.0
3400	2.94	1262	643	1890	15.5
3500	2.86	1246	659	1880	15.2
3600	2.78	1234	671	1860	14.9
3700	2.70	1220	685	1850	14.6
3800	2.63	1211	694	1826	14.4
3900	2.56	1201	704	1805	14.2
4000	2.50	1189	716	1770	14.0

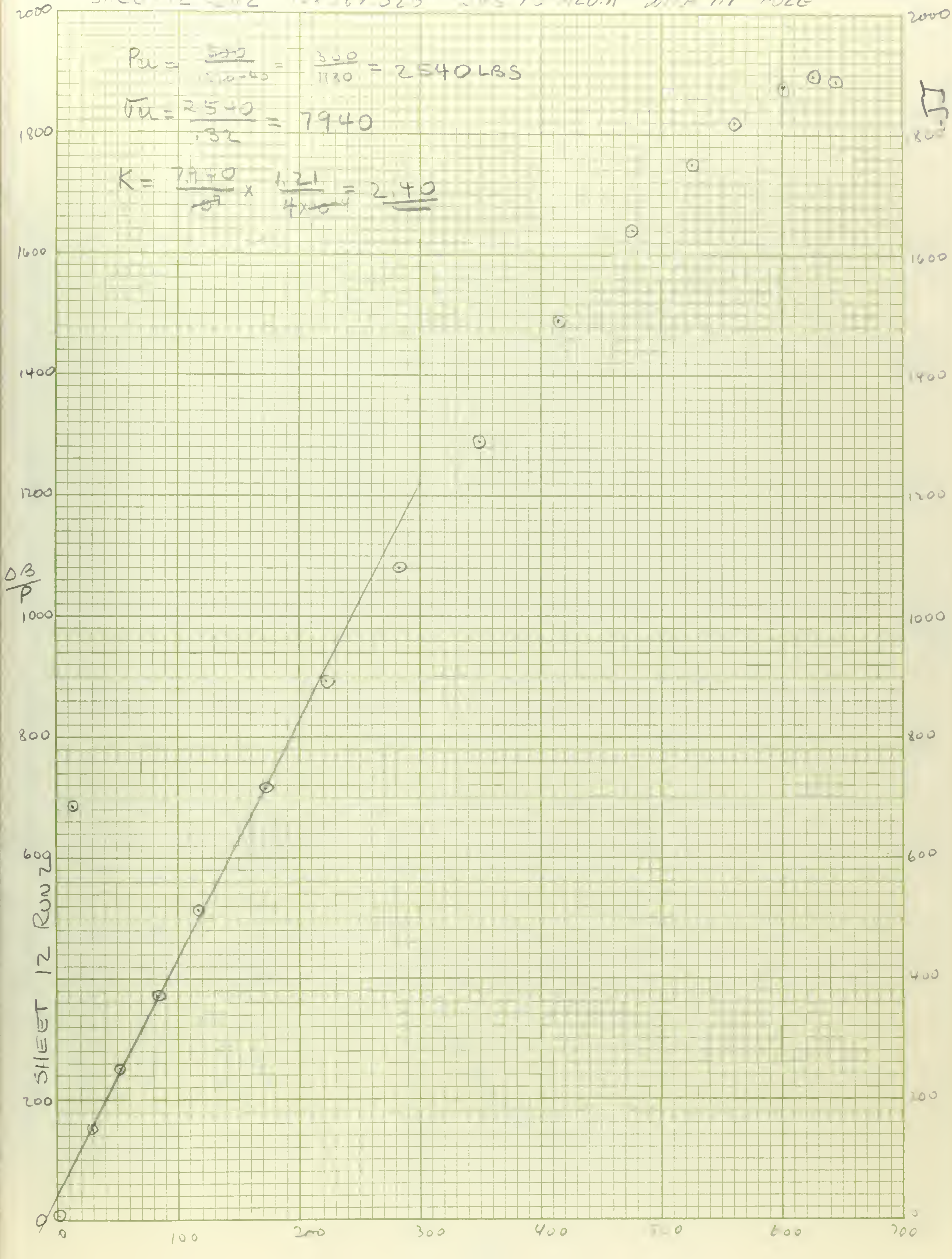
JJ

SHEET 12 RUN 2 12×36×.025" 24S T3 ALUM WITH 1.1" HOLE 5/17

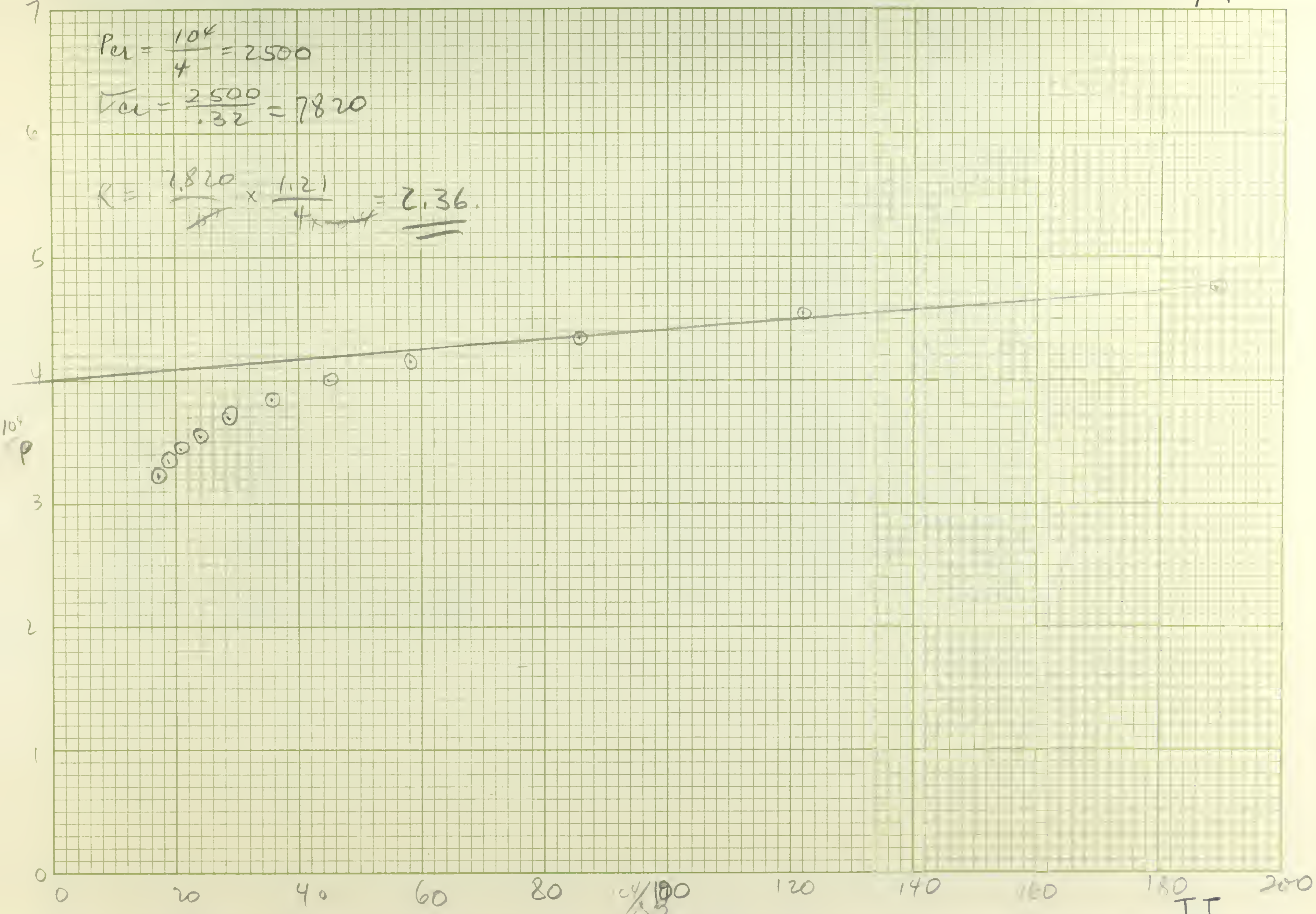
$P_u = \frac{[illegible]}{[illegible]} = \frac{300}{.1180} = 2540$ LBS

$\sigma_u = \frac{2540}{.32} = 7940$

$K = \frac{7940}{[illegible]} \times \frac{1.21}{4 \times [illegible]} = \underline{\underline{2.40}}$



SHEET 12 RUN 2   16 x 36 x .020" WITH 1.1" HOLE   24S-T3 ALUM   5/17



$P_{cr} = \frac{10^4}{4} = 2500$

$\overline{\sigma}_{cr} = \frac{2500}{.32} = 7820$

$K = \frac{7.820}{\cancel{[illegible]}} \times \frac{1.121}{\cancel{4 \times [illegible]}} = \underline{\underline{2.36.}}$

JJ

P	$10^4/P$	B	ΔB	$\frac{\Delta B}{P}\times10^4$	$\frac{10^4}{\Delta B}$
0		1778			
100		1292			
200		1195			
300		1202			
400		1225			
500		1273			
600		1348			
700		1412			
800		1482			
900		1562			
1000		1637			
1100		1710			
1200		1772			
1300		1826			
1400		1874			
1500		1901			
1600		1918			
1700		1932	0		
1800		1932	0		
1900	5.76	1918	14	73.0	714
2000	5.00	1900	32	160	313

P	$10^4/P$	B	ΔB	$\frac{\Delta B}{P}\times10^4$	$\frac{10^4}{\Delta B}$
2100	4.76	1882	50	238	200
2200	4.54	1843	89	404	112
2300	4.35	1809	123	535	81.3
2400	4.16	1758	174	725	57.5
2500	4.00	1708	224	895	44.6
2600	3.84	1642	290	1115	34.5
2700	3.70	1587	345	1276	29.0
2800	3.57	1510	422	1505	27.6
2900	3.44	1458	474	1634	21.1
3000	3.33	1400	532	1772	18.8
3100	3.23	1362	570	1838	17.5
3200	3.13	1331	601	1880	16.6
3300	3.03	1311	621	1885	16.1
3400	2.94	1293	639	1880	15.6
3500	2.86	1277	655	1872	15.3
3600	2.78	1258	674	1870	14.8
3700	2.70	1248	684	1848	14.6
3800	2.63	1232	700	1840	14.3
3900	2.56	1228	704		14.2
4000	2.50	1215	717		13.9

KK

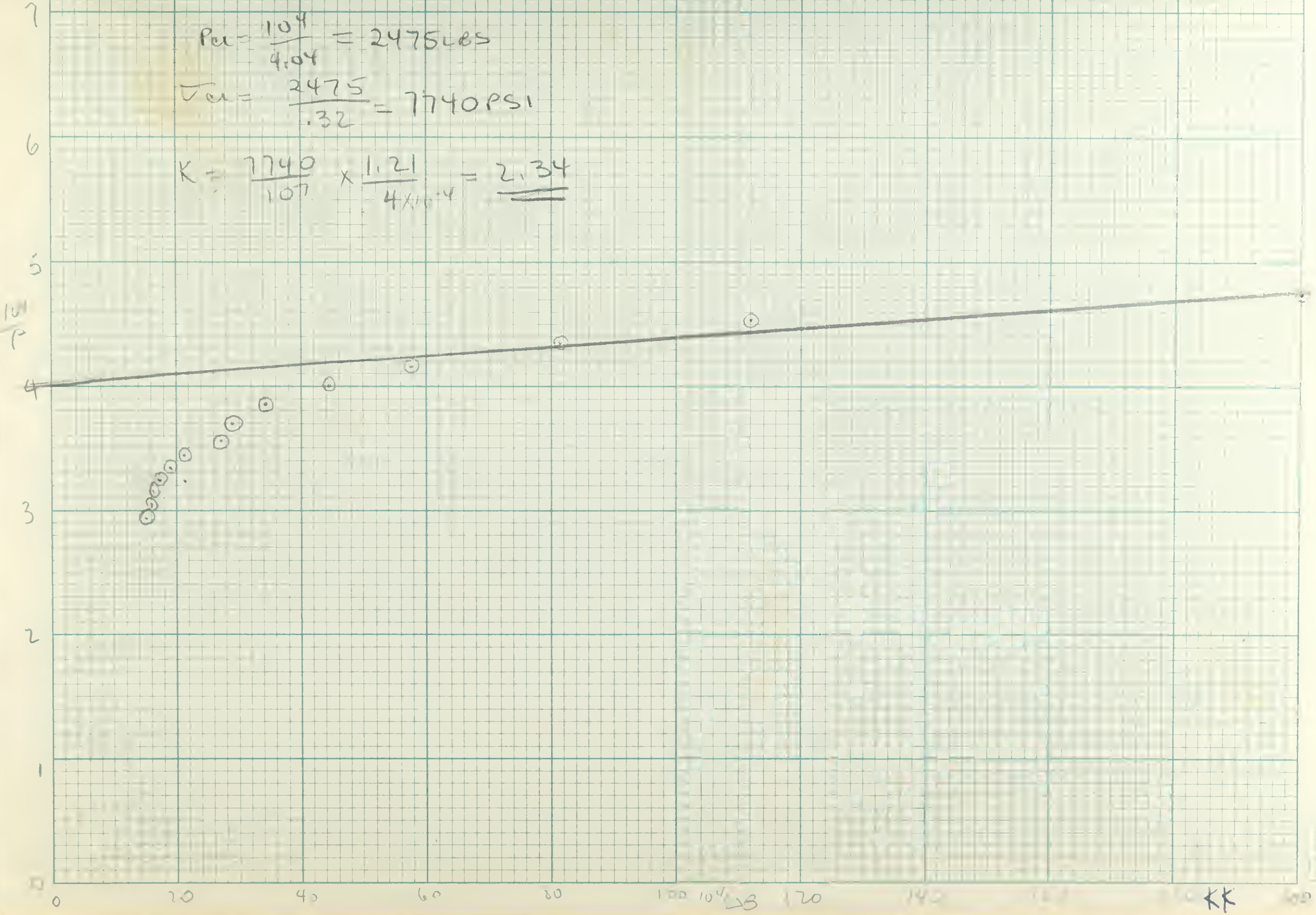
5/17

SHEET 12 RUN 3 16 X 36 X .020" 24S-T3 ALUM WITH 1.1" HOLE.

$P_{cr} = \frac{10^4}{4.04} = 2475$ LBS

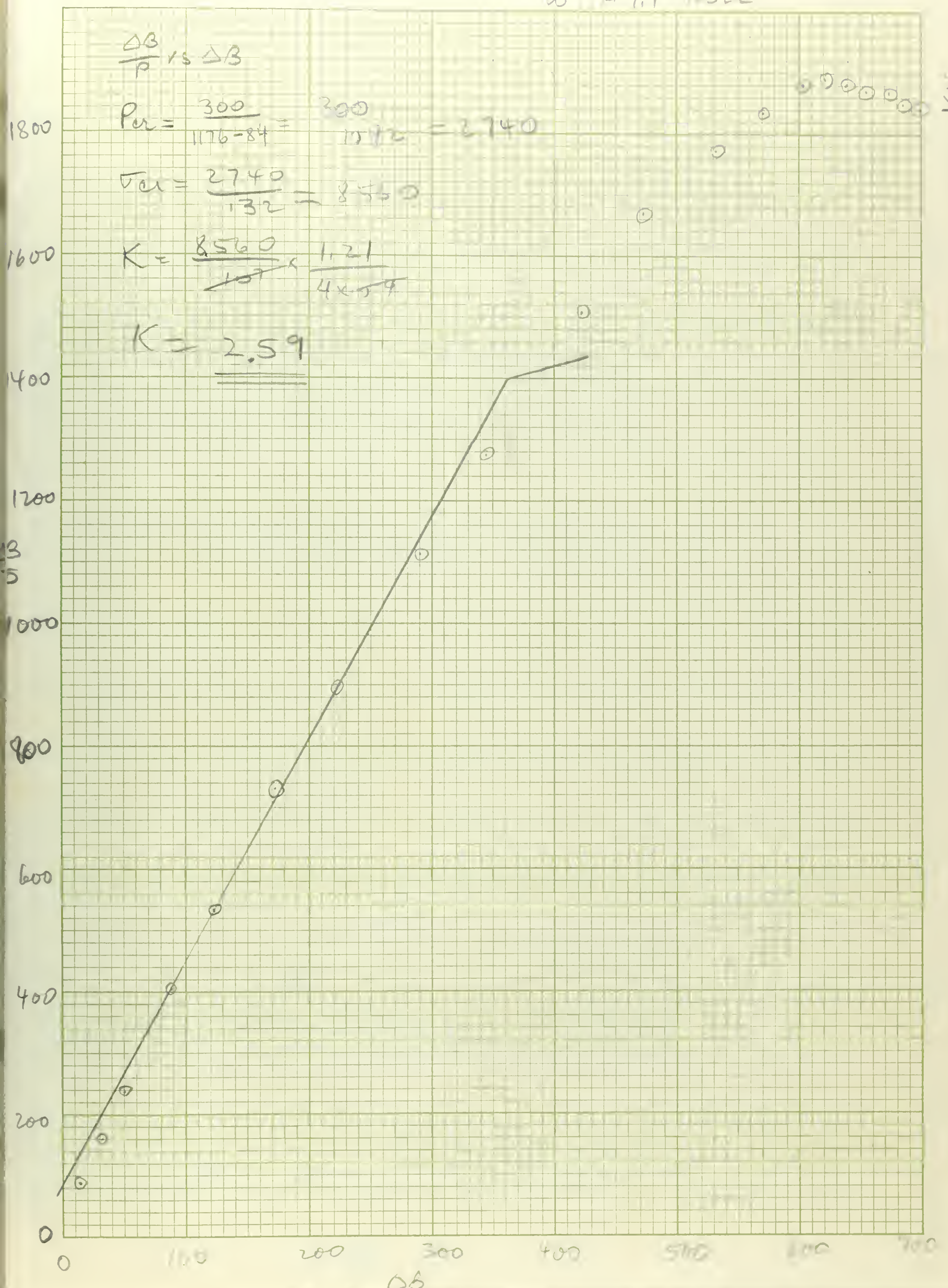
$\sigma_{cr} = \frac{2475}{.32} = 7740$ PSI

$K = \frac{7740}{10^7} \times \frac{1.21}{4\times10^{-4}} = \underline{\underline{2.34}}$



KK

SHEET 12 RUN 3 16×36×.020" 24S-T3 ALUM 5/17
WITH 1.1" HOLE



$\frac{\Delta B}{P}$ vs ΔB

$P_{cr} = \frac{300}{1176-84} = \frac{300}{1092} = 2740$

$\sigma_{cr} = \frac{2740}{.32} = 8560$

$K = \frac{8560}{\cancel{107}} \times \frac{1.21}{4 \times .59}$

$K = \underline{\underline{2.59}}$

910	
910	
940	
978	
1022	
1040	
1069	
1074	
1078	0
1069	9
1072	6
1070	8
1061	17
1049	29
1052	26
1041	37
1038	40
1033	45
1035	43
1031	47
1030	48

1022	55
1010	68
1008	70
1011	67
1006	72
1001	77
987	91
985	93
985	93
980	98
975	103
969	109
962	116
951	127
949	121
942	136
938	140
928	150
918	160
900	178

P	IP	D	[illegible]	[illegible]	[illegible]
[illegible]		1000			
[illegible]		1000			
[illegible]		1030			
300		1080			
400		1126			
[illegible]		1145			
[illegible]		1178			
[illegible]		1189			
[illegible]		1200	0		
[illegible]		1199	1		
[illegible]		1188	12	120	
		1182	18	164	
[illegible]		1180	20	167	
[illegible]		1178	22	169	
[illegible]		1165	35	250	
[illegible]		1163	37	247	
[illegible]		1163	37	231	
[illegible]		1163	37	218	
[illegible]		1160	40	222	
[illegible]		1158	42	221	
[illegible]		1150	50	250	

P	IP	D	[illegible]	[illegible]	[illegible]
[illegible]		1148	52	248	
[illegible]		1148	52	236	
[illegible]		1142	58	252	
[illegible]		1142	58	242	
[illegible]		1140	60	240	
[illegible]		1136	65	250	
2700		1132	68	252	
[illegible]		1132	68	243	
[illegible]		1122	78	269	
[illegible]		1112	88	293	
[illegible]		1111	89	287	
[illegible]		1111	89	278	
[illegible]		1110	90	273	
[illegible]		1108	92	276	
[illegible]		1100	100	285	
[illegible]		1098	102	284	
[illegible]		1090	110	297	
[illegible]		1088	112	295	
[illegible]		1072	128	328	
[illegible]		1070	130	325	

P	/P	B	ΔB	[illegible]	[illegible]
0		1030			
100		1018			
200		1050			
300		1100			
400		1137			
500		1170			
600		1191			
700		1208			
800		1211	0		
900		1210	1		
1000		1208	3	30	
1100		1199	12	109	
1200		1200	11	11.6	
1300		1188	23	177	
1400		1192	19	136	
1500		1189	22	147	
1600		1190	21	131	
1700		1180	31	182	
1800		1182	29	161	
1900		1178	33	174	
2000		1162	49	245	

TIME TIME TIME

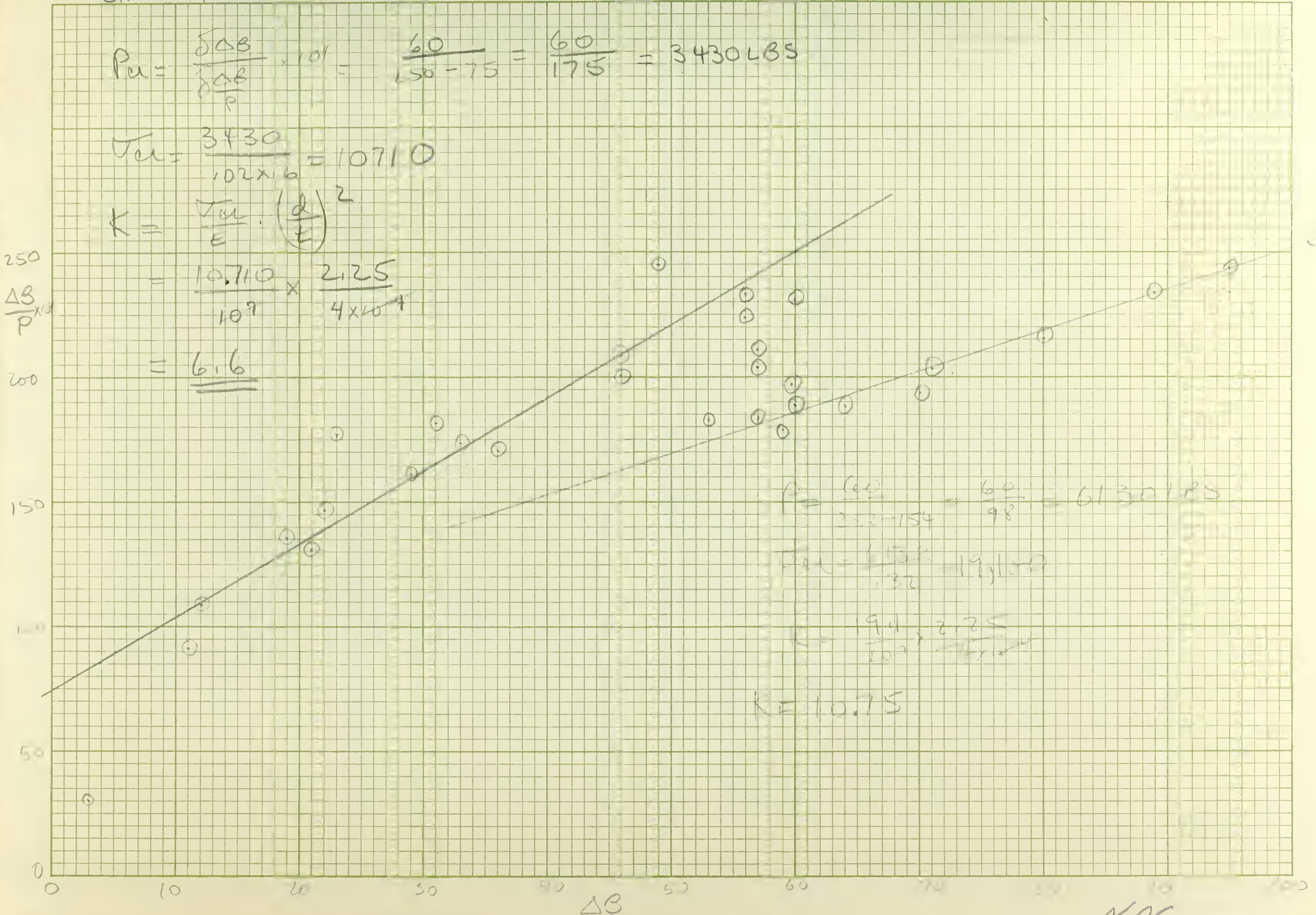
[illegible] 17 170 [illegible] 1170 [illegible] 1162/ [illegible] 1175/1641

P	/P	D	ΔB	[illegible]	/ΔB		TIME
2100		1175	36	171			
2200		1165	46	209			
2300		1165	46	200			
2400		1155	56	233			
2500		1155	56	224			
2600		1151	60	231			
2700		1154	57	211			
2800		1154	57	204			
2900		1159	53	183			
3000		1152	59	197			
3100		1154	57	184			
3200		1151	60	188			
3300		1152	59	179			
3400		1147	64	188			
3500		1140	71	203			
3600		1141	70	194			
3700		1131	80	216			
3800		1122	89	234			
3900		1115	95	244			
4000		1109	102	255			1628

NN

SHEET 14 RUN 3

1.5"



$P_{cr} = \frac{\delta \Delta B}{\delta \frac{\Delta B}{P}} \times 10^4 = \frac{60}{250 - 75} = \frac{60}{175} = 3430$ LBS

$\sigma_{cr} = \frac{3430}{.02 \times 16} = 10710$

$K = \frac{\sigma_{cr}}{E} \cdot \left(\frac{\ell}{t}\right)^2$

$= \frac{10{,}710}{10^7} \times \frac{2.25}{4 \times 10^{-4}}$

$= \underline{\underline{6.6}}$

$P = \frac{60}{252 - 154} = \frac{60}{98} = 6130$ LBS

$\sigma_{cr} = \frac{6130}{.32} = 19{,}100$

$K = \frac{19.4}{10^7} \times \frac{2.25}{4 \times 10^{-4}}$

$K = 10.75$

NN

P	L^{10}/P	B	CORRECTED FOR METER DRIFT	$\frac{}{P}\times 10^{4}$	P		B	CORRECTED FOR METER DRIFT	
0		1065			2100		1185		
100		1060			2200		1180		
200		1092			2300		1172		
300		1135			2400		1172		
400		1175			2500		1169	82	328
500		1205	17	340	2600		1164		
600		1225			2700		1162		
700		1232			2800		1159		
800		1238			2900		1151		
900		1232			3000		1150	97	323
1000		1230	33	330	3100		1142		
1100		1230			3200		1140		
1200		1222			3300		1136		
1300		1218			3400		1128		
1400		1215			3500		1128	109	311
1500		1205	48	320	3600		1119		
1600		1202			3700		1118		
1700		1200			3800		1110		
1800		1180			3900		1102		
1900		1192			4000		1099	130	325
2000		1190	65	325					
2100		1190							

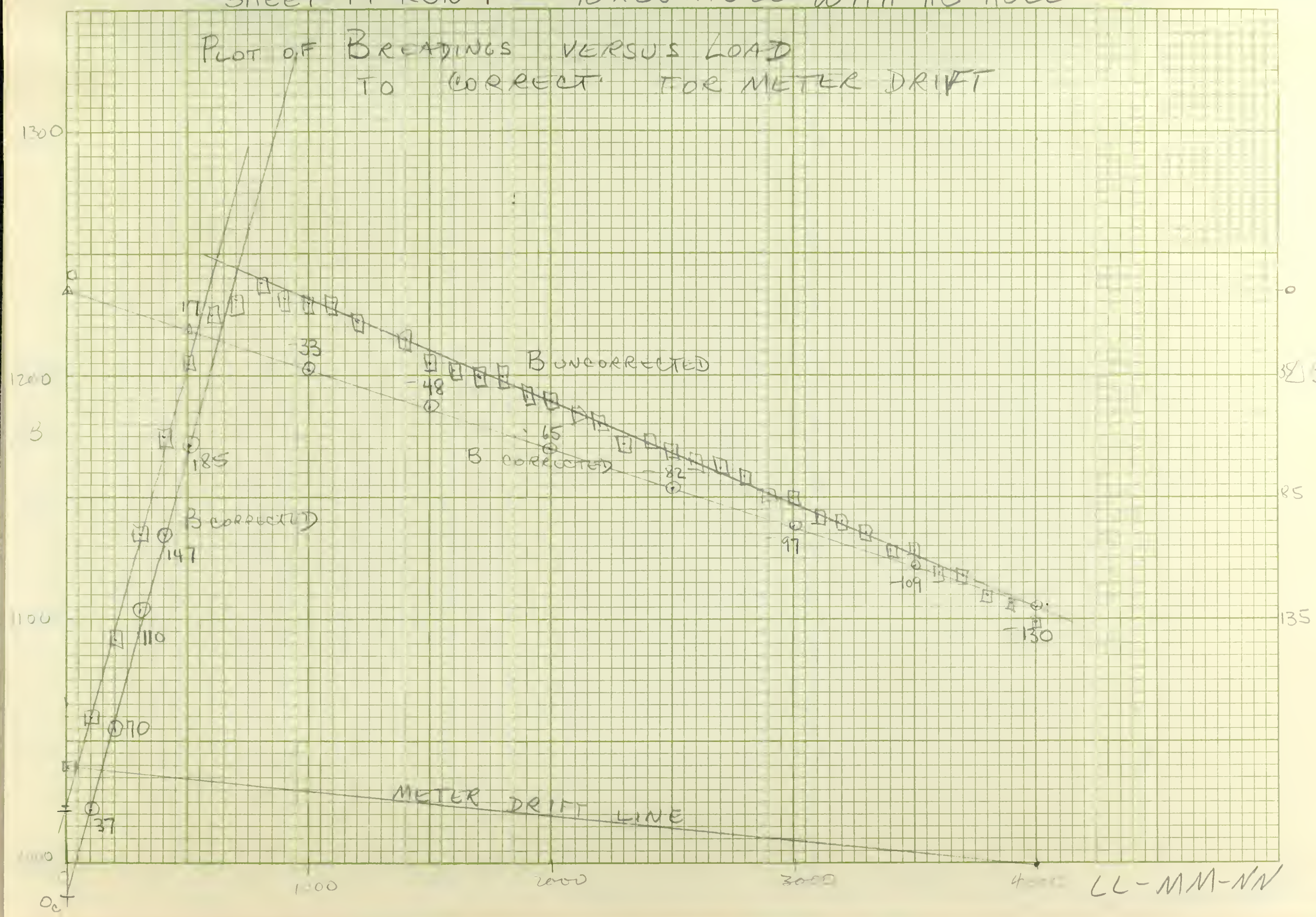
132 1010 [illegible] 1218

LL-MM-NN

P	/P	ΔB CORRECTED	/P	/ΔB
0		0		
100		37	3700	
200		70	3500	
300		110	3670	
400		147	3675	
500		185	3740	
600				
700				
800				
900				
1000				
1100				

LL-MM-1N

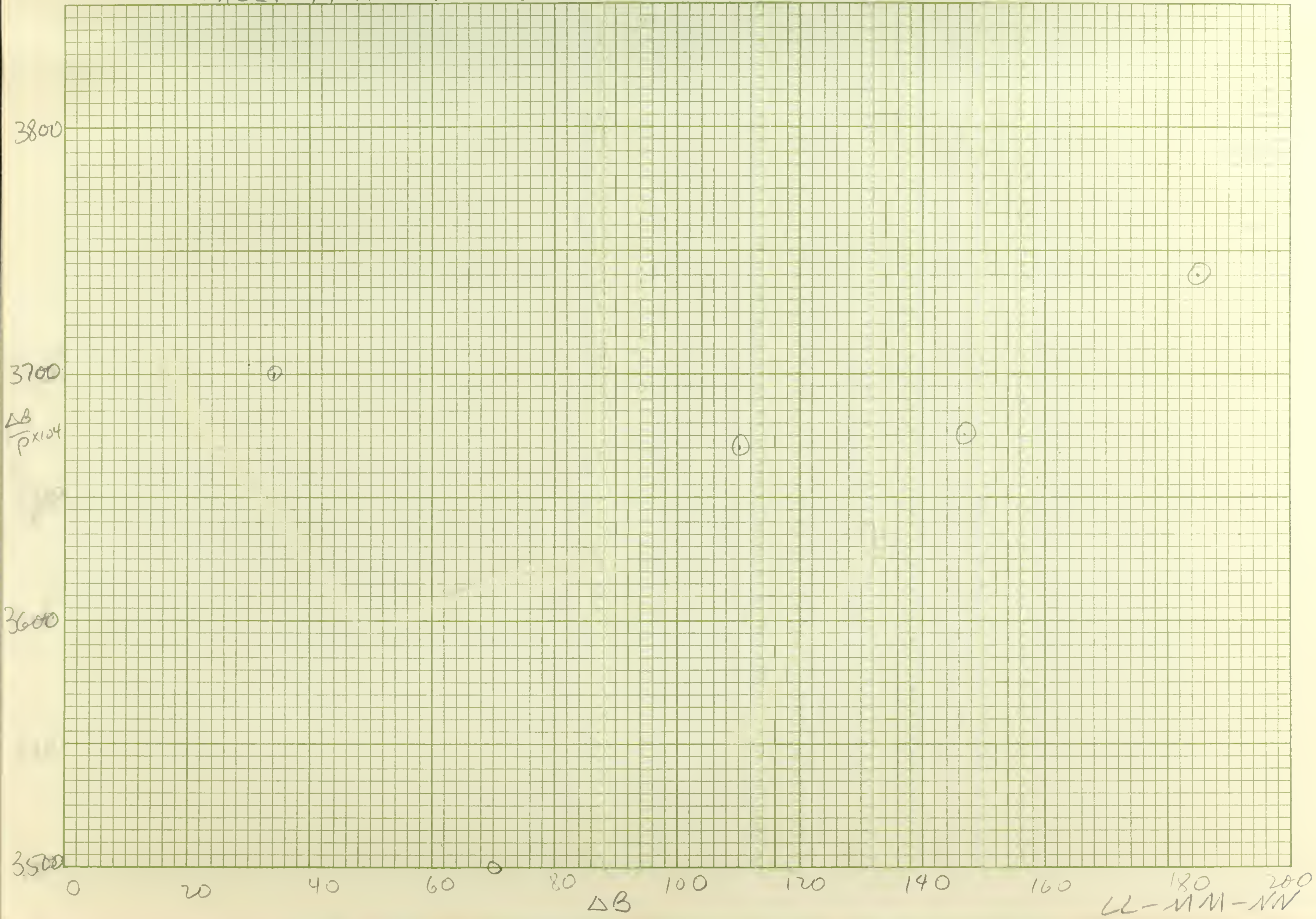
SHEET 14 RUN 4 16 x 36 x .020" WITH 1.5" HOLE



PLOT OF B READINGS VERSUS LOAD
TO CORRECT FOR METER DRIFT

LL-MM-NN

SHEET 14 RUN 4 16 x 36 x .020" WITH 1.5" HOLE 5/21



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FE 18 59
2 MAY 67
[illegible] APR 71

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BINDERY
BINDERY
15631
19352

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D1

Thesis 35703
D155 Danis
An investigation of the
buckling caused by com-
pressive forces existing
in a thin elastic sheet.

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2 MAY 67
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1039
BINDERY
15631
19352

Thesis 35703
D155 Danis
An investigation of the buck-
ling caused by compressive
forces existing in a thin elas-
tic sheet.

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An investigation of the buckling caused
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